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MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 51, No. 7.
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JULY, 1923.

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INFLUENCE OF GULF WATER-SURFACE TEMPERATURES ON TEXAS WEATHER.

By I. R. TANNEHILL, Meteorologist.

[Weather Bureau Office, Galveston, Tex., Aug. 23, 1923.]

It has been shown that the distribution of temperature over the interior of Texas and adjoining districts in the summer season, together with the direction and velocity of the prevailing winds, which in a measure result therefrom, exerts a profound influence upon the character and distribution of rainfall over that region.[1] These air currents are induced mainly by temperature differences between land and water. It is therefore necessary to determine the distribution of temperature over the water surface as well as the land surface, and, for several reasons, the former is by far the more important.

Since water has a much higher specific heat, expends a large share of its energy in evaporation, and, by its mobility, absorbs heat to a much greater depth than the land surface, its temperature changes are correspondingly more sluggish over limited ranges as contrasted with land temperature changes.

It is apparent that any given water temperature abnormality is likely to persist and its influence likely to be felt over adjacent land areas for a much longer time than a similar or even greater departure of land temperature from the normal. The assumption that abnormal weather over the United States at any season is due in part to abnormal temperatures over the oceans carries with it the assumption that ocean temperatures at various seasons depart materially from the normal. That the temperature of the ocean water exhibits a well-defined annual variation is understood, but the considerable departures from that mean annual variation are not so well known.

Dr. Hans Pettersson has said: [2]

> Important as the temperature-regulating functions of the ocean undoubtedly are, they would afford but little actual interest were they always, from year to year, exercised in exactly the same manner and with unvarying intensity. However, there is ample evidence to show that this is not the case. * * * There are years when the heat supply runs down to famine values and other years of lavish abundance. Exact proofs of this were first produced 20 years ago by Otto Pettersson, which may be said to open new perspectives on the relationship between oceanography and meteorology. By means of curves extending over many years it was shown that the surface temperatures of the Atlantic off the coast of Norway in winter vary considerably from year to year and that these variations are reflected on a magnified scale in the perfectly parallel fluctuations of the air temperature over central Sweden.

And again, in the same paper, Doctor Pettersson remarks:

> From a theoretical point of view the prevailing conditions of the surface sheet of the ocean ought to have a decided influence on the amount of rain precipitated over the continents. However, so far no very definite proofs have been produced for the actual existence of the supposed relationship. * * *

These and other investigators have found that ocean temperatures do frequently differ considerably from the normal. In a discussion of ocean temperatures and weather in southern California, William E. Ritter and George F. McEwen stated that [3]—

> During July, August, September, and October, 1917, the temperature of the sea at the institution (Scripps) averaged about 5° F. higher than for the same months of the nine preceding years and the force of the northwest ocean wind for the same time was about 20 to 30 per cent below the average. These exceptional conditions of wind and water were followed, as is well known, by exceptional weather conditions of the ensuing winter months.

Temperature of the ocean water is directly dependent upon the amounts of insolation and radiation, but the temperature of the surface water is also dependent upon the direction and velocity of the winds. Dr. Charles F. Brooks states: [4]

> Insolation and radiation are the most important factors in the general heating and cooling of the ocean surface. * * * Departures of the temperatures of the sea surface from the normal are almost wholly the result of variations in wind direction and velocity. * * * The effect of changes in wind velocity is most noticeable in the tropics, where changes in direction are of little or no effect.

It is well known that low temperatures off the west coasts of Africa and South America are due to rise of cold water from the ocean depths under the influence of trade winds.[5] Some remarkably low temperatures are found very near to the Equator due to reduction of the air temperature by cold water alongshore.

For these and other reasons it appears that considerable departures of water surface temperature from the normal are not infrequent. For the Gulf of Mexico there are available no systematic observations of water surface temperatures, but it will be shown that certain weather conditions over Texas are undoubtedly associated with unusual water temperatures.

The influence of abnormal water temperatures upon weather over adjacent land areas depends upon the magnitude of the abnormality; that is, a very cold water surface would cause a continuous overflow from water to land, and thus materially reduce the air temperature, whereas a moderately cold surface would give rise to moderate sea winds characterized by absence of cloudiness, and thus possibly produce a higher air temperature than would be the case with a higher water temperature and stagnant conditions attended by frequent rainfall and much cloudiness. In other words, a cool Gulf will not necessarily produce low temperatures over adjacent land areas.

[1] Tannehill, I. R.: Some characteristics of Texas rainfall. MO. WEATHER REV. May, 1923, 51: 250-253.
[2] Pettersson, Dr. Hans: Meteorological aspects of oceanography. MO. WEATHER REV. June, 1916, 44: 338-341.
[3] Ritter, Wm. E., and McEwen, Geo. F.: Ocean temperatures and seasonal weather in Southern California. MO. WEATHER REV., November, 1918, 46: 512.
[4] Brooke, Chas. F.: Ocean temperatures in long-range forecasting. MO. WEATHER REV., November, 1918, 46: 510-512.
[5] Hann, Dr. Julius: *Handbook of Climatology*, p. 185.

Temperature extremes along the coast are due to overflow of air from the land. Offshore winds in the daytime give rise to abnormally high air temperatures. Offshore winds at night cause low morning temperatures. A warm Gulf, then, would obviously result in low wind movement from water to land, with frequent absence of any sea wind, and thus the temperature ranges would increase correspondingly. The frequent rains and cloudiness that would result from such stagnation would act to reduce the temperature.

Now, we do know to a certainty that the Gulf surface-water temperatures rise throughout the summer months, the lag in heating being considerably more than in the case of a land surface. We may then study the changes in weather along the adjacent coast during the summer as water temperatures increase and see what characteristic changes result.

Table 1 gives a few of these. The mean wind velocity at 3 p. m., which in all summer months prevails on shore, gradually diminishes. The frequency of rainfall increases. The mean daily range of temperature increases from June to August. Sunshine decreases. These progressive changes are obviously characteristic of conditions attending a steady rise of water temperature. Temperature extremes become more pronounced. Rainfall and cloudiness are increased.

TABLE 1.—*Means for period 1913–1922, inclusive, at Galveston, Tex., illustrating progressive weather changes attending steady rise of water temperature.*

	Wind velocity, 3 p. m.	Rain frequency.	Mean daily temperature range.	Sunshine (per cent).	
				7 a. m.	Noon.
June	12.5	6.9	8.4	63	92
July	11.8	9.0	8.8	60	90
August	11.6	9.5	8.9	43	86

Of these phenomena, the wind velocity is undoubtedly the best index to water temperature. Consequently it is assumed that in certain years with excessive wind movement the water temperatures were below normal and vice versa.

In Table 2 the mean hourly wind velocities for the month of July are given for stated years in the period 1901–1922, inclusive. During that period the instruments of the Weather Bureau at Galveston were exposed continuously in the same location, with the exception that the elevation of the anemometer was increased from 112 to 114 feet in 1912, this slight change apparently having no appreciable effect on wind velocity records. The mean velocities for July are followed by means for August for corresponding years.

In the first part of the table the five years in which the July wind movement was highest have been grouped according to velocity while in the second part the five years in which July wind movement was lowest have been grouped. These data are followed by frequency of rainy days.

In the years of high wind movement, July averaged 11.1 miles per hour and August 10.4; in years of low movement, July averaged 8.3 miles per hour and the following month of those years averaged 9.3 miles. Apparently the condition which caused high wind movements in July persisted into August, though there was a trend toward normal.

TABLE 2.

	Wind velocity.		Number of rainy days.	
	July.	August.	July.	August.
1902	11.3	9.0	10	0
1915	11.2	12.8	6	11
1909	11.0	10.2	3	9
1917	11.0	10.0	3	7
1907	10.9	10.2	8	7
Mean	11.1	10.4	6.0	6.8
1919	7.1	8.8	10	10
1908	8.1	8.8	16	8
1906	8.5	8.3	11	5
1914	8.7	10.6	6	14
1916	8.9	9.9	12	11
Mean	8.3	9.3	11.0	9.6

In a similar manner the low wind movement continued into August, though increasing. These persistent conditions are thus characteristically of water origin. The frequency of rain is less in windy months. Table 3 shows the mean daily temperature range for July of those years and also the sunshine percentages. A study of this table indicates clearly that the differences in the frequency of rain, the range of temperature, and the velocity of the wind and percentage of sunshine are similar to those progressive differences that attend rising water temperature through the summer months.

It seems reasonable to conclude that in the first group of years the Gulf was cold; in the second group it was warm.

According to a compilation by Prof. A. J. Henry[6] the mean temperature for the United States as a whole was 0.5° F. lower in the first group of years than in the second, as an average.

TABLE 3.

July—	Mean daily temperature range.	Sunshine (per cent).	
		7 a. m.	Noon.
1915	8.0	69	100
1917	7.9	77	85
1902	7.9	30	81
1909	7.1	66	96
1907	7.9	48	99
Mean	7.8	58	92
1919	9.4	60	72
1914	9.0	59	97
1916	9.7	36	80
1906	9.1	44	77
1908	9.7	42	87
Mean	9.4	48	83

The greater frequency of rainfall in quiet years is due to increased opportunity for convection.[7] Note that average number of rainy days for July with excessive wind movement was 6 and for July with low wind movement 11. August of corresponding years averaged 6.8 rainy days following a windy July and 9.6 following a quiet July.

Apparently unusually high wind movement, suppressing convection in July, is likely to persist into August,

[6] Henry, A. J.: Sunspots and terrestrial temperature in the United States. Mo. WEATHER REV. May, 1923, 51 : 243–249

[7] Tannehill, I. R.: Correlation of wind velocity and convective rains at Houston, Texas, Mo. WEATHER REV., April, 1921. 40: 204–205.

reducing the rain frequency in the same manner, and conversely a quiet and, consequently, a wet July will be followed by a wind movement below normal and rainfall above normal in August. However, it must be noted that this record covers a period of little more than 20 years and that wind movement at one location on the Texas coast is discussed with reference to rainfall which results from showers quite local in character.

Of the above years, 1917 was most remarkable as far as rainfall is concerned. The total rainfall at Galveston that year was 21.43 inches, the least annual amount recorded since the record began in 1871. The average hourly velocity of the wind for 1917 was 11.8 miles, which has been exceeded in only two years of record.

Abnormally high wind movement and a total annual rainfall of 5.38 inches characterized the year at Corpus Christi. The section director at the close of December, 1917, issued in part the following summary: [8]

> December was the driest of 16 consecutive dry months, and closed the driest year of the record. The average precipitation for the State was only 7 per cent of the normal * * *. The deficiency was general, and three-fifths of the reporting stations had less than a measurable amount of precipitation.

A persistently high wind movement of this character suggests the maintenance of an abnormally steep temperature gradient from land to water, with the probability that the source lies in low water temperature. Under the heading "Weather Conditions over the North Atlantic Ocean," the WEATHER REVIEW in 1918 included summaries for the year 1917. These were partially as follows:

> January: For the month under discussion the water temperatures were somewhat below the normal over practically the entire ocean. * * *
>
> February: The monthly average temperature of the water at the surface was considerably below the normal over the entire ocean with the exception of the region in the vicinity of the Azores and the Madeiras and within the northeast trade wind limits, where the positive departures ranged from 1 to 3 degrees. * * *
>
> March: * * * while in the vicinity of the American coast and in the Gulf of Mexico they were variable, although slightly negative over the greater portion of this territory.
>
> April: The mean monthly surface water temperatures as compared with the normal were about as variable as those of the air. * * *
>
> May: * * * In American waters, including the Gulf of Mexico, negative departures were the rule. * * *
>
> June: The average monthly temperature of the air over the ocean did not, as a rule, vary greatly from the normal. * * * In the Gulf of Mexico they were slightly negative, * * * while over the remainder of the ocean the air and water temperature departures did not differ materially. * * * (Indicated that water temperatures of Gulf were slightly below normal.)
>
> July: In the northeast trade wind region and Gulf of Mexico the departures were rather irregular, ranging from minus 1° to plus 4°.
>
> August: The mean temperature of the water at the surface differed but little from that of the air. * * * (Nearly normal in Gulf of Mexico.)
>
> September: * * * in the Gulf of Mexico they were slightly negative—* * *
>
> October: * * * as well as in the Gulf of Mexico, the water temperatures were as a rule from 1° to 4° below the normal.
>
> November: In the Gulf of Mexico the water temperatures were from 2° to 3° lower than usual— * * *
>
> December: The temperatures for the greater part of the northern steamer lanes were somewhat cooler than usual, the same conditions holding true in the Gulf of Mexico and in the waters adjacent to the American coast, * * *

The records indicate that for most of the year 1917 the Gulf water temperatures were somewhat below normal. Such a condition sets up strong temperature gradients and results in increased wind movement over Texas, thus suppressing convectional rains. As a result ranges in 1917 were poor, stock water was scarce, movement of cattle to prevent starvation began in June and continued to the close of the year. Dry weather was unfavorable for crops and poor stands resulted. A large acreage was prepared for winter grain, but most was not sown on account of dry weather.

Table 1 contains data that indicate that dry weather caused by high wind movement is likely to persist. The suggestion is offered that abnormal conditions like those of 1917 are the result of low Gulf water temperatures. It seems more than likely that the temperature of the Gulf water was below the normal during the entire year and that abnormally high wind movement set up thereby served to keep the waters in motion and thus prevent the normal accumulation of warm surface water that would have naturally terminated the abnormal temperature gradient. In short the condition is likely to persist both because of the wind movement set up and because water, by its mobility, high specific heat, and evaporation, responds very sluggishly in temperature changes.

Since changes in the velocity and direction of the prevailing winds over Texas influence the character and distribution of its rainfall (1) and exert a profound influence upon the crop yield, grazing of cattle, and in other ways vitally affect the prosperity of this region, the possibility of long range forecasts based upon a very thorough study of water and land temperatures and other factors demand attention.

The year 1919, with the lowest annual wind movement recorded at Galveston since the anemometer was placed in its present exposure, was an abnormal year over Texas. Data shown in the foregoing tables would indicate that the Gulf in July of that year was abnormally warm. In that respect it was the reverse of the extreme year of 1917 and the effect on the weather of the State was pronounced and its influence upon crops was strikingly in contrast to that of 1917.

The section director in his annual summary for Texas stated:[9]

> The year 1919 was the wettest of record from and including 1888 * * *. The excessive precipitation resulted in damaging floods, reduced the cotton crop, deteriorated late corn, stimulated insect pests, and delayed plowing, seeding, and harvesting and other farm work. Cottonseed began to sprout in the bolls and rice and grain in the shock, and peanuts, sweet potatoes, and feed crops were beginning to rot in the fields * * *.

No water temperature records for the Gulf are available for the year 1919.

In conclusion, it can not be said that the evidence is indubitable. The records discussed are rather local in character as regards wind velocity, temperature ranges, and sunshine percentages. Yet the conditions shown therein give every evidence of being fundamentally related to the weather over the State.

It has been shown that the variation in these conditions in July of various years is similar to the variation which results in those conditions from one summer month to the succeeding as the water temperature changes. In the most striking of the windy and dry years, which were assumed to attend an abnormally cold Gulf, it has been shown that in every probability the Gulf surface water temperatures, from reliable records for a portion of the year, were continuously below normal throughout the year.

If, then, abnormal water temperatures are responsible for such striking variations in the weather over the State and the crop yields and in general the comfort and prosperity of the population, or if there is a probability that such is true, it seems highly important that the distribution of water surface temperatures be as well known as that of the land surface.

[8] *Climatological Data for the United States by Sections;* Vol. IV, Part IV, p. 135.

[9] *Climatological Data for the United States by Sections:* Vol. VI, Part V, p. 148.

ACCURACY OF AREAL RAINFALL ESTIMATES.

By ROBERT E. HORTON, Consulting Hydraulic Engineer.

(Voorheesville, N. Y., July 10, 1923.)

Benton's rule.—A question has probably arisen in the mind of almost everyone having to do with areal rainfall estimates as to the dependability of the results. Such estimates when based on a sufficient number of good precipitation records are generally accepted as fairly reliable. The number of records available is, however, often limited, and the question naturally arises, What is the relative accuracy of two rainfall estimates for the same area, one based on a very large number and the other on a limited number of records? Rainfall estimates sufficiently accurate for one purpose may not be so for another purpose. Something more than a mere qualitative opinion as to the accuracy of areal rainfall estimates is therefore desirable.

According to Sir John Benton [1]—

> The least number of rainfall stations inside the boundaries of a catchment area which will afford a reasonably safe estimate of the rainfall may be assumed to be as follows:

Square miles area.						
From	0	50	100	200	350	500
To	50	100	200	350	500	750
Stations needed	1	2	3	4	5	6

Since there can be no fractional stations, at least two stations must be used in accordance with this rule for an area of 50 to 100 square miles, and so on.

Benton's table is approximately represented by the formula—

$$N = 1 + \frac{1}{5}\sqrt{A} \qquad (1)$$

where A is the area in square miles. This rule is evidently intended to apply in the hilly countries of England and India where rainfall often varies rapidly with change of position, but where also the rainfall records are numerous, so that the requirements of the rule can often be complied with.

In the United States, outside of certain limited areas in the East, rainfall stations are seldom more frequent than one or two to the county or about one to every 660 square miles. As many stations as are required by Benton's rule are seldom available, but it does not follow that "reasonably safe" estimates of rainfall are not obtainable in the United States, especially in regions where the topography is flat and local variation of rainfall comparatively small.

Relation of rainfall range to accuracy.—The accuracy of an estimate of areal rainfall—assuming always that the individual records used are reliable—seems to depend primarily on two things:

1. The actual range of rainfall within the area.
2. The number of records used.

The accuracy depends only indirectly on the size of the area, since in general the larger the area the larger is the range of rainfall variation within its boundaries. If, for example, the rainfall gradient is uniform along the axis of a drainage basin, then the range would vary with the length or approximately as the square root of the area. For a given number of stations the accuracy of the average is proportional to the range of variation between the amounts for the different stations.

From the laws of probability it is well known that the probable error of the mean of a number of observations varies inversely as the square root of the number. The same relation holds for the average error and other measures of precision. In other words, the probable error of an areal rainfall estimate can be expressed in the form—

$$\delta = K\frac{R}{\sqrt{N}} \qquad (2$$

where R is the range, N the number of stations, and K a constant. If the range varies as the square root of the area, then in order that estimates shall have equal accuracy for the areas A_1 and A_2,

$$\sqrt{\frac{A_1}{N_1}} = \sqrt{\frac{A_2}{N_2}}$$

or the number of stations must be directly proportional to the size of the area instead of varying with the square root. Variation of rainfall range with $\sqrt{A}$ often holds approximately for small areas of similar physiography and exposure, but for large areas the range of rainfall may increase but little with increase of area, justifying the use of a smaller number of stations per unit area as the total area increases, as in Benton's table.

In general the range can be accurately determined from the available records for any given area, and it is better to express results as to accuracy directly in terms of range rather than in terms of area and avoid the uncertainty as to the relation of range to area. Formula (2) applies only in case the rainfall stations are not separately weighted or in case they are given equal weights, as where a straight arithmetic mean is taken. The range is determined by taking the greatest difference in mean annual rainfall at any two points within the area.

Derwent River Basin records.—The rainfall record for the basin of the River Derwent in England [2] affords an opportunity to test the agreement of experience with theory in this matter and to determine the numerical coefficient K in formula (2). Forty-two rain gages were maintained within an area of 48.87 square miles. Most of the records are complete for the 13 years 1900 to 1912, inclusive. In a few cases the record for 1900 has been supplied by interpolation using the formula—

$$P = \frac{P_a}{P_m}P_1.$$

Where P = required precipitation for 1900 at a given station.

P_1 = mean precipitation at the same station for the other years.

P_a = mean of the precipitation for 1900 at all stations having records.

P_m = mean precipitation at all stations.

Figure 1 shows the topography of the area, the locations of the rain gages, the 13-year mean for each, and the isohyetal lines. This is a rugged hilly region well dissected by streams, with precipitation generally increasing proceeding upstream.

[1] Buckley Irrigation Pocketbook, 3rd ed., 1920, p. 324.

[2] Sandeman, Proc. Inst. C. E., vol. 194, 1912-13. (H D, 7-1-22.)

Average error of arithmetic means.—In view of the large number of stations within the Derwent Basin, the true average rainfall was assumed to equal the arithmetic mean of all the records. This was checked by the application of the Thiessen method and also by planimeter measurement of the areas between contours. The errors which would have resulted if the average rainfall had been determined by taking the arithmetic means of different numbers of stations ranging from 1 to 20 was obtained by random selection of sets of the required numbers of stations. The stations were chosen by drawing their numbers from a box, the only restriction being that all stations drawn should not be adjacent. This was done for the reason that if, as an example, there were only two stations within the area and these were adjacent, they would properly be treated as in effect equivalent to a single station. In such cases the results of a second drawing were substituted. A complete drawing of each set was made independently in each case except for sets or groups of 14 to 20 stations. For these groups, to avoid excessive labor, cumulative drawing was used—that is, a station selected at random was added to each group to give the next higher group. To provide a check on the results, two series of drawings were made for all groups. The average departures of the computed rainfall as determined from a given number of stations from the true mean are summarized in Table No. 1. The results are shown graphically on Figure 2 in conjunction with a curve computed from the formula—

$$\delta = \frac{14.7\ R}{\sqrt{N}} \qquad (3)$$

where δ is the average departure of the mean as determined from N stations from the true mean, expressed as a percentage of the range R.

TABLE 1.—*Average departure of mean rainfall determined by different numbers of stations from true mean, Derwent Basin, Eng.*

Number of stations used.	Number of sets drawn in each series.	Average departure from true mean.		Average of both series.	Per cent of range in mean annual rainfall.
		First series.	Second series.		
(1)	(2)	(3)	(4)	(5)	(6)
1	42	.....	.....	4.19	15.6
2	30	2.601	2.108	2.35	8.75
3	30	2.388	2.290	2.34	8.71
4	30	2.572	1.934	2.25	8.38
5	30	1.938	1.745	1.84	6.85
6	30	1.953	1.356	1.65	6.14
7	30	1.922	1.286	1.60	5.96
8	30	1.319	1.213	1.27	4.73
9	30	1.574	1.006	1.29	4.81
10	30	1.399	1.108	1.25	4.65
12	[1]15–[2]30	1.296	1.065	1.18	4.40
14	[1]15–[2]30	1.214	.952	1.08	4.02
16	[1]15–[2]30	.877	.985	.93	3.44
18	[1]15–[2]30	.807	.855	.83	3.09
20	[1]15–[2]30	.788	.800	.79	2.94

[1] Series 1. [2] Series 2.

Mean rainfall=46.50 inches. Range in mean=26.86 inches.

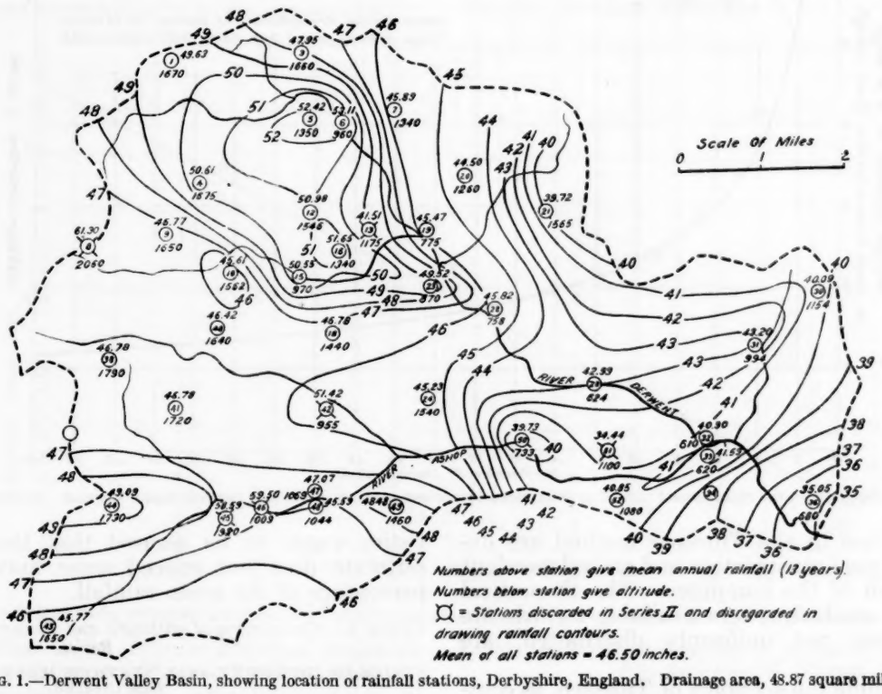

Scale Of Miles
0 1 2
RIVER DERWENT
RIVER ASHOP
Numbers above station give mean annual rainfall (13 years).
Numbers below station give altitude.
= Stations discarded in Series II and disregarded in drawing rainfall contours.
Mean of all stations = 46.50 inches.

FIG. 1.—Derwent Valley Basin, showing location of rainfall stations, Derbyshire, England. Drainage area, 48.87 square miles.

Since there were only 42 stations, the plotted points on Figure 2, if extended, would show a departure approaching zero for $N=42$, whereas actually the departure should approach zero as a limit as N approaches infinity. Points for large values of N used in this study lie below the curve of Figure 2, as they should. Aside from this the plotted points faithfully confirm the applicability of the inverse square root rule to the average error of areal rainfall estimates. Expressed in terms of the true average rainfall over the area the average error of a rainfall estimate derived from the arithmetic mean of N stations is:

$$\delta = \frac{14.7\ R}{P\sqrt{N}} = \frac{0.147\ Z}{\sqrt{N}} \qquad (4)$$

where R is the range or difference between the greatest and least rainfall amounts in inches within the area, P is the approximate mean areal rainfall, and Z is the range ratio in per cent of P, or

$$Z = 100 \times \frac{R}{P}. \qquad (5)$$

Comparative average errors of arithmetic and Thiessen means.—The Thiessen method of estimating the rainfall over an area consists in applying to each record within or adjacent to the area a weight proportional to the percentage of that area to which the given station lies nearer than any other station.[3]

Thiessen means approaches zero as the number of stations increases. In Series IV certain stations, the records for which were apparently abnormal as compared with the several surrounding stations, were omitted. Series V was confined to the Alport Basin, a subdivision of the Derwent Basin.

Maximum departure and assured accuracy of areal rainfall estimates.—The preceding studies show the average departure, or what amounts to the same thing, the probable departure of an estimate based on a limited number of records from the true mean. This is not the same as "the probable error" of statistics, but corresponds to the "average error;" that is to say, the studies afford no assurance that the actual error of a given estimate may not be considerably greater. The user of rainfall statistics wants to be assured that the error of a given estimate does not exceed some maximum or limiting percentage of the mean rainfall.

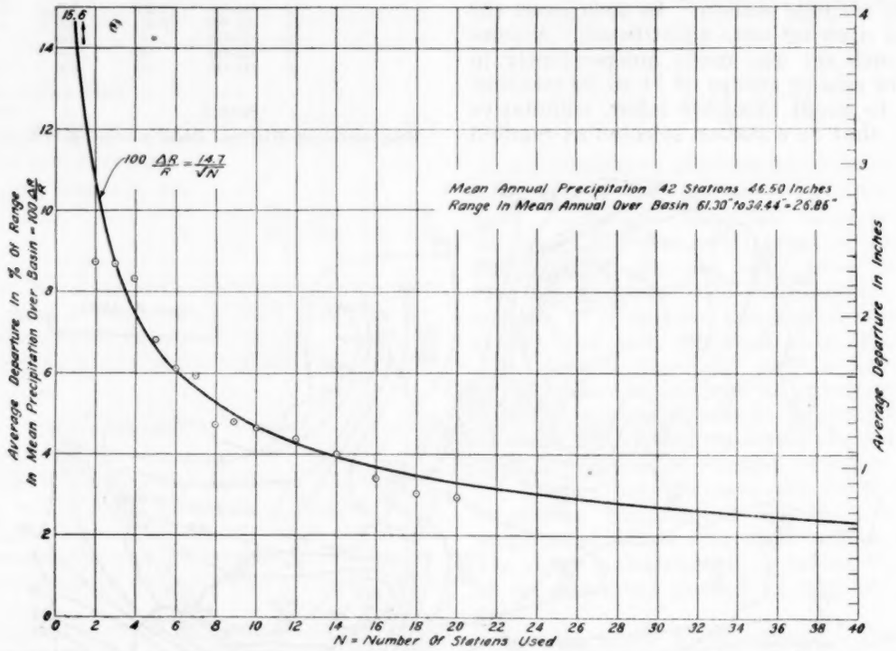

15.6
100 ΔR/R = 14.7/√N
Mean Annual Precipitation 42 Stations 46.50 Inches
Range In Mean Annual Over Basin 61.30"-34.44"=26.86"
Average Departure In % Of Range In Mean Precipitation Over Basin = 100 ΔR/R
Average Departure In Inches
N = Number Of Stations Used

FIG. 2.—Average error in the mean annual rainfall as determined by various numbers of stations, Derwent Basin, England. Arithmetic mean.

The weights for use in the Thiessen method are determined by geometrical construction and are independent of personal equation of the computer. The theoretical advantages of this method, where available records are few in number and not uniformly distributed, are obvious.

In order to determine the accuracy of Thiessen, as compared with arithmetic, means, three series of groups of different numbers of stations were drawn and the means computed, both arithmetically and by Thiessen's method. The average errors of the two methods are shown in Table No. 2. The number of groups drawn for each number of stations is shown in column 2. In the subsequent columns the average departures are expressed in terms of inches, percentage of true mean, and percentage of range, respectively. It will be noted that in general there is a slight advantage in favor of accuracy of the true mean derived by Thiessen's method, where the number of stations available is small. This study was not extended to include groups of more than eight stations, since the difference between the arithmetic and

TABLE 2.—*Comparison of arithmetic and Thiessen mean rainfall Derwent Basin.*

SERIES III, DERWENT.—ALL STATIONS MEAN[1] 46.50 INCHES, RANGE[2] 26.86 INCHES.

Number of stations used.	Number of groups drawn.	Average departure from true mean arithmetic method.			Average departure from true mean Thiessen method.		
		Inches.	Per cent of true mean.	Per cent of range over basin.	Inches.	Per cent of true mean.	Per cent of range over basin.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	42	4.19	9.0	15.6	4.19	9.0	15.6
2	70	2.93	6.30	10.9	2.76	5.93	10.3
3	10	2.91	6.25	10.8	2.20	4.73	8.20
4	10	2.19	4.71	8.2	2.53	5.44	9.05
5	5	2.18	4.69	8.1	1.57	3.37	5.85
6	5	1.20	2.58	4.5	1.03	2.21	3.8
7	5	1.11	2.39	4.1	.85	1.82	3.2
8	5	1.65	3.55	6.1	1.32	2.84	4.9

[1] 13-year arithmetic mean of all stations used.
[2] Difference between highest and lowest 13-year record.

[3] Horton, Robert E.: Rational Study of Rainfall Data, Eng. News-Record, Aug. 2, 1917, pp. 211–213.

SERIES IV, DERWENT.—ABNORMAL STATIONS OMITTED, MEAN 45.72 INCHES, RANGE 17.37 INCHES.

Number of stations used.	Number of groups drawn.	Average departure from true mean arithmetic method.			Average departure from true mean Thiessen method.		
		Inches.	Per cent of true mean.	Per cent of range over basin.	Inches.	Per cent of true mean.	Per cent of range over basin.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	36	3.18	6.95	18.3	3.18	6.95	18.3
2	9	2.27	4.96	13.1	1.95	4.26	11.2
3	5	1.19	2.60	6.9	.86	1.79	4.7
4	3	1.91	4.17	11.0	1.58	3.45	9.1
5	2	.78	1.70	4.5	.77	1.68	4.4
6	4	.83	1.81	4.8	.48	1.05	2.9
7	2	.56	1.22	3.2	.99	2.16	5.7

SERIES V, ALPORT BASIN.—MEAN[3] 49.70 INCHES, RANGE 16.07 INCHES.

1	9	4.57	9.2	30.9	4.57	9.2	30.9
2	50	3.04	6.11	18.9	2.90	5.83	18.1
3	50	2.44	4.91	15.2	2.36	4.75	14.7
5	50	1.55	3.12	9.6	1.85	3.72	11.5
8	50	.94	1.89	5.8	1.52	3.06	9.6

[3] Average of the Thiessen and arithmetic means for the basin using all stations.

N increased, the figures probably do not show the true maximum departure in case of large numbers of stations. This is indicated by the fact that all the plotted points for more than 10 stations fall well below the envelope line AB.

In the case of Thiessen means the number of groups averaged for each value of N is not sufficient to determine the formula for maximum error, but is sufficient to determine the relative magnitude of the maximum errors of the two methods for different numbers of stations. The results derived from Series No. 4 are summarized in Table 4, in which the right hand columns show the difference between the maximum errors of the two methods for a given number of stations expressed as a percentage of the range. The maximum error of the Thiessen mean is smaller for groups of two to eight stations in all cases but one, and as an average the maximum error of the Thiessen mean for two to eight stations is less than that of the arithmetic mean by 5.1 per cent of the range of variation of rainfall within the area. In other words, the assured accuracy of the Thiessen mean for a limited number of stations is greater than for the arithmetic mean by about 5 per cent of the range.

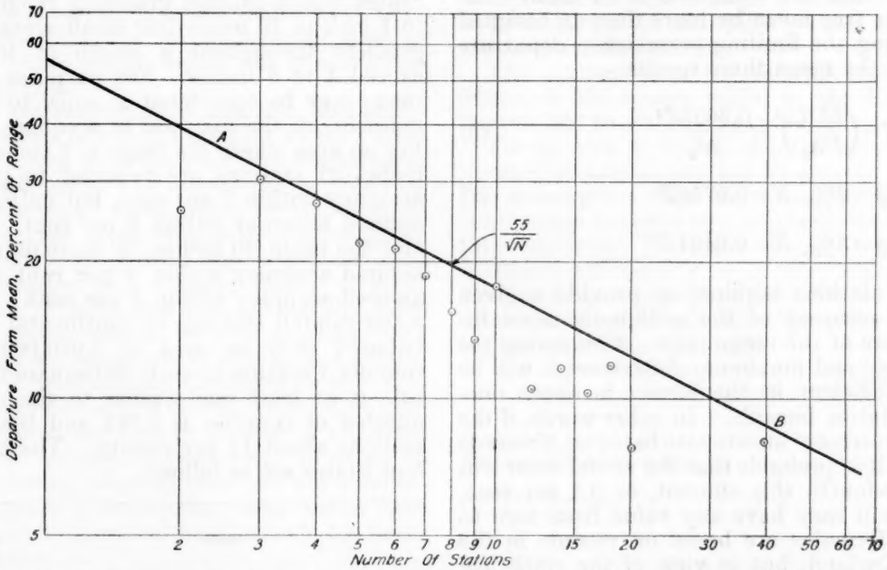


FIG. 3.—Derwent River Basin, maximum departure from true mean rainfall of estimates based on arithmetic means of different numbers of stations.

Without attempting to fix definite limits of desirable accuracy for such estimates it will serve for illustration to assume that in precise scientific investigations, as in determining water losses or for final studies of run-off, the maximum error of the rainfall estimate should, if possible, be kept within 2 per cent of the mean. For rough estimates and preliminary studies an assured accuracy of 5 per cent may be all that is required. In order to determine the greatest error which may be liable to occur in a given areal rainfall estimate, the maximum departure of the computed from the true means was determined from each set of groups of N stations used in the studies already described for Series 1 and 2, using arithmetic means only. The maximum departure for either series for a given number of stations and the results expressed in various forms are given in Table 3. The maximum departures expressed as percentages of the range and plotted logarithmically are shown on Figure 3. The equation of the upper envelope of the plotted points, as shown by the line AB on Figure 3, again follows the inverse square root law. Inasmuch as the number of groups of N stations used in this study decreased as

TABLE 3.—*Maximum departures of arithmetic mean of N stations from true mean rainfall, Derwent Basin.*

Mean annual rainfall on basin=46.50 inches.
Range in annual rainfall on basin=26.86 inches.

No. of stations N.	Maximum departure of any single group.		Larger of 2.	Per cent of range in annual rainfall.	Per cent of mean annual rainfall.
	Series I.	Series II.			
(1)	(2)	(3)	(4)	(5)	(6)
1	14.80	14.80	14.80	55.1	31.8
2	6.94	5.76	6.94	25.8	14.9
3	7.68	8.17	8.17	30.4	17.6
4	6.65	7.25	7.25	26.9	15.6
5	5.74	5.91	5.91	22.0	12.7
6	5.79	4.98	5.79	21.5	12.4
7	5.05	4.33	5.05	18.8	10.9
8	4.02	4.20	4.20	15.6	9.03
9	3.64	3.28	3.64	13.6	7.82
10	4.73	3.17	4.73	17.6	10.2
12	2.71	2.82	2.82	10.5	6.06
14	3.14	2.53	3.14	11.7	6.75
16	2.81	2.80	2.81	10.4	6.04
18	3.21	2.51	3.21	11.9	6.90
20	2.10	2.04	2.10	7.8	4.50

TABLE 4.—*Maximum departures of arithmetic and Thiessen means from true mean rainfall with different numbers of stations, Derwent Basin, England.*

Mean annual rainfall on basin=46.50 inches.
Range in annual rainfall on basin=26.86 inches.

Number of stations.	Arithmetic mean.			Thiessen mean.			Difference in per cents of range.
	Maximum departure of a single group.	Per cent of range in annual rainfall.	Per cent of mean annual rainfall.	Maximum departure of a single group.	Per cent of range in annual rainfall.	Per cent of mean annual rainfall.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	14.80	55.0	31.8	14.80	55.0	31.8	0
2	9.64	35.8	20.7	7.10	26.4	15.3	9.4
3	7.58	28.2	16.3	5.95	22.1	12.8	6.1
4	4.68	17.4	10.1	5.16	19.2	11.1	−1.8
5	3.22	12.0	6.92	3.01	11.2	6.47	0.8
6	3.37	12.5	7.25	1.55	5.78	3.33	6.7
7	3.51	13.1	7.55	1.85	6.88	3.98	6.2
8	3.06	11.4	6.58	2.06	7.66	4.44	3.7

Average of 2 to 8 stations, 4.4 per cent.

It is now possible to determine the number of records necessary in order that the estimated areal mean shall not depart from the true mean by more than an assigned amount. Expressing the limiting permissible departure Δ_g as a per cent of the mean there results—

$$N=\left(\frac{55\mathrm{R}}{P\Delta_g}\right)^2=\frac{0.3025Z^2}{\Delta^2{}_g} \tag{6}$$

or for

$$\Delta g=2\%,\ N=0.0756Z^2 \tag{7}$$

$$\Delta g=5\%,\ N=0.0121Z^2 \tag{8}$$

The number of stations required to provide a given assured degree of accuracy of the arithmetic mean increases as the square of the range ratio. Comparing the formulas for average and maximum departures it will be noted that the coefficient in the former is about one-fourth that in the latter formula. In other words, if the indicated maximum error of an estimate based on N records is 2 per cent, then it is probable that the actual error will be only about one-fourth this amount, or 0.5 per cent, although of course it may have any value from zero to 2 per cent. The formulas are based on records in the hilly country of England, but in view of the statistical nature of the data and the method of treatment by ratios there appears to be no reason why the formulas are not applicable elsewhere as well. This seems to follow for the reason that the statistical law of distribution of, for example, shot around the bull's eye of a target can be determined as well for a given range and rifle from observations in United States as in England.

It is to be noted that the dominant factor controlling the accuracy of areal rainfall estimates is the range ratio, or the amount of fluctuation in rainfall within the area as compared with the areal mean. It is at once evident that it may be difficult to secure a high percentage of accuracy in rainfall estimates in arid regions where the mean is small and the range ratio relatively large. In extremely wet regions greater accuracy may often be obtained, although there may be a much larger actual range, for the reason that the relative range or range ratio is usually less over an area of a given size in regions of high than in regions of low rainfall. Again, it is obviously much more difficult to secure a high degree of accuracy for estimates in mountain regions with high rainfall gradients than for areas of equal size in flat countries where the rainfall gradient is often small and comparatively uniform. Generally speaking, the rainfall range increases with the size of the area, although it may be nearly as great for a comparatively small as for a much larger area, especially in a region where the rainfall is comparatively uniform.

For the entire Mississippi River Basin the range ratio is roughly—

$$100\,\frac{60-10}{30}=167\%$$

$$\Delta_g=Z\sqrt{\frac{0.3025}{N}} \tag{9}$$

There are at present at least 1,600 rainfall stations maintained in the Mississippi Basin, so it appears that the areal mean for this basin can be determined with an assured accuracy within 2.3 per cent and with a probability that the actual error is much less. For small areas the case is different. Throughout much of the Central States region rainfall gradients range from 1 inch in 5 to 1 inch in 10 miles over small areas, whereas the total gradient throughout a length of 100 miles may not exceed 4 to 6 inches. For purposes of comparison the range may be considered as equal to the product of the gradient by the diagonal of a square equal to the area. For an area where the range is 5 inches and the mean 30 inches 21 stations are required to provide an assured accuracy within 2 per cent, but only 3.4 stations for an assured accuracy within 5 per cent. If the range is 10 and the mean 30 inches, 53 stations are required for an assured accuracy within 2 per cent and 8 or 9 for an assured accuracy within 5 per cent. There are roundly 4,500 rainfall stations in continental United States distributed over an area of 2,970,000 square miles, or roundly 1 station to each 660 square miles. The general rule is at least one station to the county. The total number of counties is 2,741 and the actual number of stations about $1\frac{2}{3}$ per county. The areas per station in four States are as follows:

State.	Area, square miles.	Stations.	Area.
Ohio	40,760	122	334
Michigan	57,430	123	466
New York	47,620	130	366
Massachusetts	8,040	25	321

In Massachusetts, with 1 Weather Bureau station to 321 square miles and with an average rainfall gradient of about 1 inch in 5 miles, the assured accuracy for areas of different sizes containing the usual numbers of stations is as follows:

Area (square miles).	Stations.	Range.	Range ratio.	Δ_g.
4	1	2	0.56	0.31
25	1	5	1.4	0.77
100	1	10	2.8	1.54
900	3	30	8.4	2.67
1,600	5	40	11.2	2.7
2,500	8	50	14.0	2.7
3,600	11	60	16.8	2.8
4,900	15	70	19.6	2.8
10,000	31	100	28.0	2.8

For large areas an accuracy of the arithmetic mean within 2.8 per cent is attainable under these conditions. For small areas the values of $\triangle_g$ above given are applicable only in case a rainfall station happens to fall actually within the area. The chance that this will occur is proportional to the ratio of the area to the area per station, or 321 square miles for Massachusetts. In case a station does not happen to fall within the area there is no certain method of determining the maximum departure of an estimate from the true mean except by assuming that the range is equal to the difference between the rainfall amounts at two adjacent stations, which for Massachusetts would average 18 miles, giving a range of 3.6 inches applicable to any area of less than 321 square miles.

SUMMARY.

The preceding considerations show—

1. That a high degree of reliability may be assured even where the mean rainfall over a small area is determined from a single station, provided the station falls within the area.

2. It is impracticable by the use of direct averages to obtain a high degree of certainty in the estimates of rainfall over small areas with the station spacing such as now exists in the United States unless one or more stations fall within the area.

Clearly it is also impracticable to establish and maintain a sufficient number of rainfall stations so that areal means can be determined accurately by direct arithmetic averages for all small areas. Of course the accuracy of rainfall estimates for small areas which do not contain any rainfall station may often be greatly improved by interpolation methods. In general the long-term areal means can be determined with a higher degree of accuracy than the means for individual years or months, since as a rule there are more rainfall records available in a given area than there are contemporaneous stations maintained on the area. For example, Goodenough has compiled 120 rainfall records, each of several years' duration, which have been kept at one time or another in the State of Massachusetts, an average of one record to every 67 square miles. Of course, many of these are not simultaneous, but for purposes of estimating areal means they can often be reduced to identical base periods by Fournie's or other methods.

The average error and maximum error of arithmetic areal rainfall means both vary inversely as the square root of the number of stations used.

The probable average error and maximum error or assured accuracy of an areal rainfall estimate can be determined by the use of the simple formulas summarized below.

The number of stations required to limit the error to a specified percentage of the mean varies as the square of the range ratio.

It requires only about 16 per cent as many stations to secure an assured accuracy within 5 per cent of the true mean as within 2 per cent.

The average error of an estimate is about one-fourth of the maximum error.

The arithmetic mean and Thiessen methods give identical results for a single station, and also for a very large number of stations.

For a limited number of stations, say, two to eight, the maximum error which can result from the use of the Thiessen method is less than that from the use of the arithmetic mean by an amount equal to about 5 per cent of the range.

For conditions within the United States it is possible to secure an assured accuracy of an arithmetic mean areal rainfall within 3 per cent for very large areas.

The arithmetic means for areas of 1,000 square miles or more can often be obtained with an assured accuracy within 2 per cent in the United States in regions of fairly uniform rainfall.

For very small areas an assured accuracy within 2 per cent can generally be obtained if one or more rainfall stations exist within the area.

The chance that a station exists within a given area is proportional to the ratio of the area to the average area per rainfall station.

The average area per rainfall station in the United States is 660 square miles; in the Eastern and Central States, 300 to 400 square miles.

For an area in which there is no rainfall station the assured accuracy may not be greater than that based on the assumption that the range on the area equals the total range between two adjacent outside stations.

In applying Thiessen's method the assumed assured accuracy will usually be at least equal to that indicated by the formulas given where N is the total number of stations to which Thiessen's method applies, whether within or outside the basin.

SUMMARY OF FORMULAS.

Error of arithmetic mean:	Average departure. $\delta =$	Maximum departure. $\Delta =$
Per cent range	$\frac{14.7}{\sqrt{N}}$	$\frac{55}{\sqrt{N}}$
Inches	$\frac{0.147\,R}{\sqrt{N}}$	$\frac{.55\,R}{\sqrt{N}}$
Per cent mean	$\frac{14.7\,R}{P\sqrt{N}}$	$\frac{55\,R}{P\sqrt{N}}$
Per cent mean	$\frac{0.147\,Z}{\sqrt{N}}$	$\frac{0.55\,Z}{\sqrt{N}}$

N, number of stations in area.
R, absolute range within area, inches.
P, approximate areal mean, inches.
Z, range ratio, per cent of mean $= 100\,\frac{R}{P}$.

RAINFALL DURATION AND INTENSITY IN INDIA.

By ROBERT E. HORTON, Consulting Hydraulic Engineer.

[Voorheesville, N. Y., July 10, 1923.]

The annual rainfall in India ranges from a minimum of less than 4 inches to a maximum of over 450 inches at Cherrapunji. In view of the sharp demarcation between the wet and dry seasons afforded by the monsoon climate generally prevailing, this region affords favorable opportunity for study of the relation between rainfall amount, duration, and intensity. Data of amount of rainfall and rainfall duration in days for over 2,000 stations, having records covering 20 years or more, have been published in the *Memoirs of the Indian Meteorological Department*. The records were grouped according to the amount of rainfall, and the means of the long-term average rainfall and of the average numbers of rainfall days were taken for all stations in a given group and the resulting average number of inches of rain falling per rainfall day were computed. These data are shown in the subjoined table. It is to be noted that in India only days on which one-tenth inch or more precipitation occurred are counted as rainfall days. A total of 2,207 stations was included in the calculation, the group means of rainfall ranging from 6.6 inches per year for stations having less than 10 inches, up to 239.8 inches for stations having over 200 inches per year, the number of rainfall days ranging from 13.3 per year for the group having lowest rainfall, to 140.6 per year for the group having over 200 inches of rainfall. The average amount per rainfall day ranges from 0.5 inch for stations with less than 10 inches to 1.70 inches for stations with over 200 inches per year. There is a consistent progressive increase in the number of rainfall days and amount per rainfall day as the rainfall increases throughout all the records.

The group means of the number of rainfall days were plotted in terms of the mean annual precipitation, as shown by the lines designated (2–a) and (2–b) on Figure 1. Small circles indicate the plotted points. For rainfalls of less than 100 inches per annum the relation is nearly linear and a line designated (3) was drawn showing the relation between the data for this portion of the diagram. The group means of the average amounts per day were also plotted, as indicated by the lines designated (1) and (4) and by triangular symbols. It will be noted that there is a sharp change in the relation between annual rainfal and average amount per day corresponding to a rainfall of 95 inches. For smaller amounts the average rainfall per day is represented by a curve convex upward, while for larger amounts of rainfall per year, the amount per day apparently bears a linear relation to the amount per year. Empirical formulas for the different relation curves were developed as shown on the diagram. The first four formulas are based on the assumptions, first, that up to a rainfall of 100 inches the number of rainfall days is a linear function of the annual rainfall amount; and second, that for rainfalls exceeding 100 inches per year the amount per day is a linear function of the annual rainfall amount. From the fact that the annual rainfall equals the product of the number of rainfall days and the average amount per day, the corresponding formulas for the number of

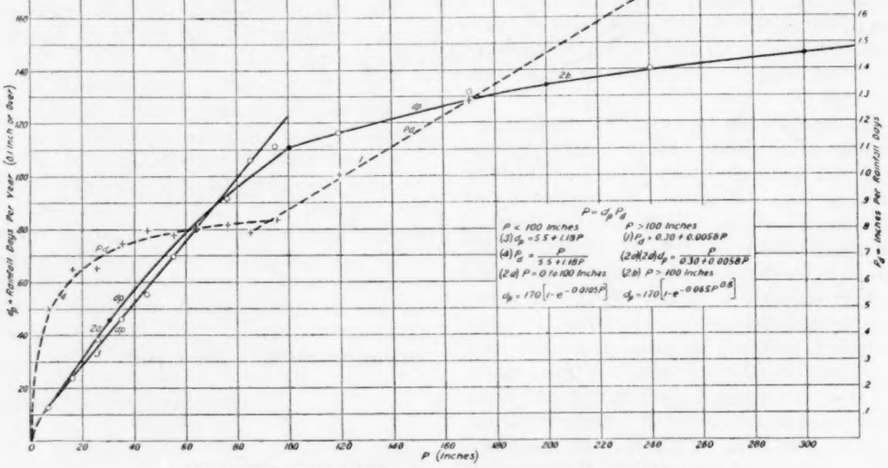


FIG. 1.—Relation of rainfall amount, duration, and intensity in India.

rainfall days in the first instance and amount per day in the second instance were easily deduced.

It appeared at once that none of the four formulas thus far described was wholly rational, as the formulas for rainfall days both indicate that the number of rainfall days per year could be infinite if the amount of precipitation was only large enough. Actually, the number of rainfall days per year can not, of course, exceed 365, and practically owing to the seasonal interchange of the monsoons, the number of rainfall days can not exceed about one-half this number or, say, 180 days per year. The highest number of rainfall days for any single station of record is 161.7, corresponding to a rainfall of 457.8 inches at Cherrapunji. The connected curves (2–a) and (2–b) indicate that the number of rainfall days is a function of the amount of rainfall, probably of exponential form, and approaching a maximum limit of less than 180 as the rainfall increases indefinitely. Accordingly, an attempt was made to represent this curve by an equation of the form,

$$d_p = a[1 - e^{-kp^n}]$$

It was found, however, impossible to fit the entire curve of rainfall days by a single formula. Separate con-

stants are necessary to adapt this equation to the portions of the curve representing numbers of rainfall days per year at stations having over 100 inches, and less than 100 inches rainfall per year, respectively. Two equations of this form, which taken together are in excellent agreement with the plotted points, are shown on the diagram, and the heavy lines (2–a) and (2–b) are plotted from values calculated by these equations. While it seems probable that this type of equation represents a rational form of relation between the number of rainfall days and the amount of rainfall per annum at a given location, there is no reason to expect that the constants in the equation should be uniform over so wide a geographical range of territory as India affords.

Apparently, however, for stations in India having more than 100 inches of rain, a single formula will give approximately accurate results for all stations, and a separate formula will apply equally well to all stations having less than 100 inches of rain. Stations having over 100 inches of rain are mostly at high elevations and their high rainfall is largely due to orographic conditions. Where these conditions exist it may naturally be expected that the relation between the rainfall amount and duration will differ from that pertaining at coastal stations or in flat regions.

As illustrating the probable variation of the number of wet days at a single station from the mean for the same amount of rainfall the data were tablulated for the 61 stations having rainfall amounts between 19 and 21 inches, respectively. For rainfall between 19 and 21 inches, there are 6 cases with the number of days between 22.8 and 25, 24 cases with the number of days between 25 and 30, 25 cases with the number of days between 30 and 35, 2 cases with the number of days between 35 and 40, 4 cases with the number of days between 40 and 45; least number of days, 22.8; greatest number of days, 43; mean number of days, 30.1.

The chance is 4 to 5 that departure for a single station will not exceed one-fifth the mean number. Inspection of the complete data shows similar relations to hold for larger rainfall amounts.

Summer rainfall rate and duration in India.

Amount.		Number of stations.	Average inches per year.	Average number rain days.	Average inches day.
From—	To—				
0	10	91	6.6	13.3	0.50
10	20	158	15.8	24.2	.65
20	30	496	25.4	38.7	.66
30	40	443	34.9	46.6	.75
40	50	333	44.6	55.5	.80
50	60	207	54.9	70.1	.78
60	70	1[illegible]	64.4	80.6	.80
70	80	67	75.7	92.4	.82
80	90	49	84.8	106.8	.79
90	100	60	94.5	111.9	.84
100	150	144	118.8	116.7	1.01
150	200	34	169.6	132.0	1.28
200+	.....	14	239.8	140.6	1.70

ARE WE HAVING LESS SNOWFALL?

By CLARENCE J. ROOT, Meteorologist.

[Weather Bureau Office, Springfield, Ill., Aug. 24, 1923.]

Central Illinois experienced a very light snowfall during the winter of 1922–23; in fact, there have been several successive winters with rather light amounts. This has led numerous persons to make remarks similar to this: "We do not have the big snows that we did when I was a boy, and I do not think we will ever have them again." Is it true that we do not have the big snows that we did, or is it a matter of viewpoint? No doubt the snow that reached to the shoulder of the small boy of the seventies and eighties does not seem very deep to the mature man of 1923. Then, again, many of our city men lived in the country as boys, where the wind has full sweep over the prairies and large drifts are piled up.

Although the snowfall at Springfield has been rather light during several of the more recent winters, the greatest fall of record, 43 inches, occurred as late as the winter of 1913–14. The Springfield winter totals have been averaged for periods of 10 years, beginning in 1884, with the following results: 20.3, 19.6, 21.9, and 20.3 inches. Thus it will be seen that there has been no material change in 40 years. The largest fall in December occurred in 1915, in January in 1918, in February in 1900, and that of March in 1906.

The Illinois climatological reports make mention of heavy snows in recent years. In January, 1912, there was as much as 21 inches in the southern part of the State, with individual falls of 15 inches. On February 22–23, 1914, a severe snowstorm occurred in central Illinois. The wind piled the snow into deep drifts, the snow being 5 to 15 feet deep in places. Business was almost at a standstill and railroad lines were demoralized.

January of 1918 was the severest month in the climatological history of Illinois. The low temperature and heavy snowfall, combined with strong winds, were very unusual. The average snowfall was almost double that of any previous January, and was considerably more than that of any previous month. The greatest total, 42.5 inches, occurred at Chicago, where the most unusual snowfall conditions in the history of the city occurred. The storm of the 6th was the severest since the weather station was established in 1871, but that of the 11th was still more so. The storm of the 11th was of the blizzard type and extended over the entire State, causing the most general and complete transportation paralysis in many years, if not in the history of Illinois railroads. Deep drifts formed, in many cases covering hedges and fences, and many wagon roads were completely blocked even as late as the end of the month. Trains were stalled all over the State. On many sections of main-line railroads there was no train movement for two or three days, and branch lines were blocked for a longer period, 10 days in one case.

During a single week of March, 1923, unusually heavy snow fell over Wisconsin and northern Illinois. At Freeport, Ill., the snow reached an accumulated depth of 25 inches. For Wisconsin the monthly average was the greatest of record for March.

In discussing this subject it may be of interest to know what has happened in other States. The following statement with reference to the winter of 1922–23 was made by Dr. C. F. Brooks in the *Bulletin of the American Meteorological Society:*

There was an extraordinary amount of snowfall in New England during the last winter. December had two times the normal amount. In January the snowfall in northern New England was twice and in the southern portion three times the average. This was followed by the usual amounts in February and March. At Portland the January

fall was 53 inches, and the winter's total exceeded 10 feet. All highways were absolutely impassable for automobiles from the first week in January to the last week in March.

Through the kindness of several of the station officials, the writer has secured comparative snowfall data for a number of the more Northern States. At Albany and New York the snowiest winter occurred more than 30 years ago, but there have been only six winters with more snow than fell in that of 1922–23. The records at New Haven extend back to 1873, and the data have been averaged by 10-year periods, beginning with the earliest records, with the following results: 48.8, 40.8, 42.3, 39, and 35.6 inches. A gradual falling off is indicated at New Haven, yet the heaviest of record occurred as late as the winter of 1915–16, and last winter the total was 19 inches above the normal.

Another old record is that of Boston, beginning with 1871. Our friends who believe the climate is changing might find comfort in learning that the greatest seasonal snowfall of record at Boston (96.4 inches) was in 1873–74, but the winter with the least snow (5.3 inches) was only two years later. By 10-year periods, commencing with 1873, the averages are: 44.1, 47, 44.5, 39.8, and 47.6 inches. The last is the greatest. Just as was the case at Albany and New York, the snowfall of the winter 1922–23 has been exceeded but six times. The total was 24.3 inches above the normal.

At Portland, Me., the greatest total snowfall for a winter (125.5 inches) occurred in 1886–87, but last winter, with but one-half inch less, was next in amount. The decade averages at Portland are: 74.8, 77, 72, and 75.9 inches. The heaviest snowfall of record at Northfield, Vt. (193 inches) occurred during the winter of 1887–88, but the second greatest was in a recent winter, that of 1921–22, and the fourth greatest just two years earlier. Rochester, N. Y., is an especially snowy place. The greatest fall (142 inches) was in 1900–1901; the least, in 1918–19. The averages by decades (10-year periods) at this station are: 76.1, 99.3, 71, and 78.3 inches. Buffalo had the greatest total in 1909–10 and the least 20 years earlier. In the West we find that Cheyenne's winter of least snow was back in 1885–86 and the greatest some 19 years later. The greatest total of record at Salt Lake City occurred in the winter of 1916–17, and the second, third, and fourth since then. The following figures are given by way of comparison, the dates indicating the winter of greatest snowfall: Columbus, 1909–10; Detroit, 1899–1900; Helena, 1880–81; Lincoln, 1914–15; Spokane, 1889–90.

There is evidence enough to permit persons in certain localities to really believe that the days of heavy snowfall are past, but viewing the subject in a broad way we are led to conclude that there will undoubtedly be heavy snows in the years to come just as there have been in the past, and it is probable that present records will be exceeded at many places.

THE NATIONAL ELIMINATION BALLOON RACE FROM INDIANAPOLIS, IND., JULY 4, 1923.

By L. T. SAMUELS, Meteorologist.

[Weather Bureau, Washington, D. C., August 20, 1923.]

The three contestants covering the greatest distance from the starting point in this event are chosen to represent the United States in the International Balloon Race—a sporting event in which contestants compete for a cup donated in 1906 by the late James Gordon Bennett. Although, as has been stated, this is a sporting event, there is extensive opportunity during these races for obtaining information of value to the science of meteorology. For this reason it has been customary for the Weather Bureau, in events of this sort, to contribute from its knowledge of wind conditions both on the surface and in the free air such information as may be of value to contestants.

Mr. C. G. Andrus was again the Weather Bureau observer in the race acting as aid to Mr. R. H. Upson, while the writer was assigned to Indianapolis for the purpose of giving the contestants first-hand information obtained from special pilot-balloon observations made at Indianapolis and at a number of surrounding Weather Bureau and Army aerological stations. In addition to the arrangements made for having this detailed information directly available at the starting place, the district forecaster at Chicago forwarded special advices for the balloonists.

Arrangements were also made to have telegraphed to Indianapolis on July 2, 3, and 4 the computed free-air pressures from a number of stations east of the Rocky Mountains. This made possible the drawing of charts depicting the atmospheric pressure at 1,000 and 2,000 meters above sea level.[1] This phase of Weather Bureau work is of recent development and it may be said that this was the first occasion of its practical application. Further reference to these charts will be made later.

Radio bulletins were issued on the evening of the 4th and the morning of the 5th from Chicago, Detroit, Schenectady, and Washington for the benefit of those balloons that were equipped with receiving sets. Only four of the balloonists availed themselves of this source of information, the winner being one of these.

It seems proper, first, to describe the dominant features of the controlling pressure areas a few days previous to the race. The weather over Indiana on the morning of July 1 was anticyclonic, the result of a high-pressure area centered over New England which was becoming merged with the permanent HIGH over the Atlantic and accompanied by relatively low pressure north of the Canadian border. This HIGH over New England had previously crossed the United States with a rate of movement greater than normal. On the next day the Atlantic HIGH continued in control causing moderate to fresh southwest winds above 1,000 meters. By the morning of the 3d there was evidence of a condition approaching stagnation, typical of the summer season, while thunderstorms were becoming general over the Lake region.

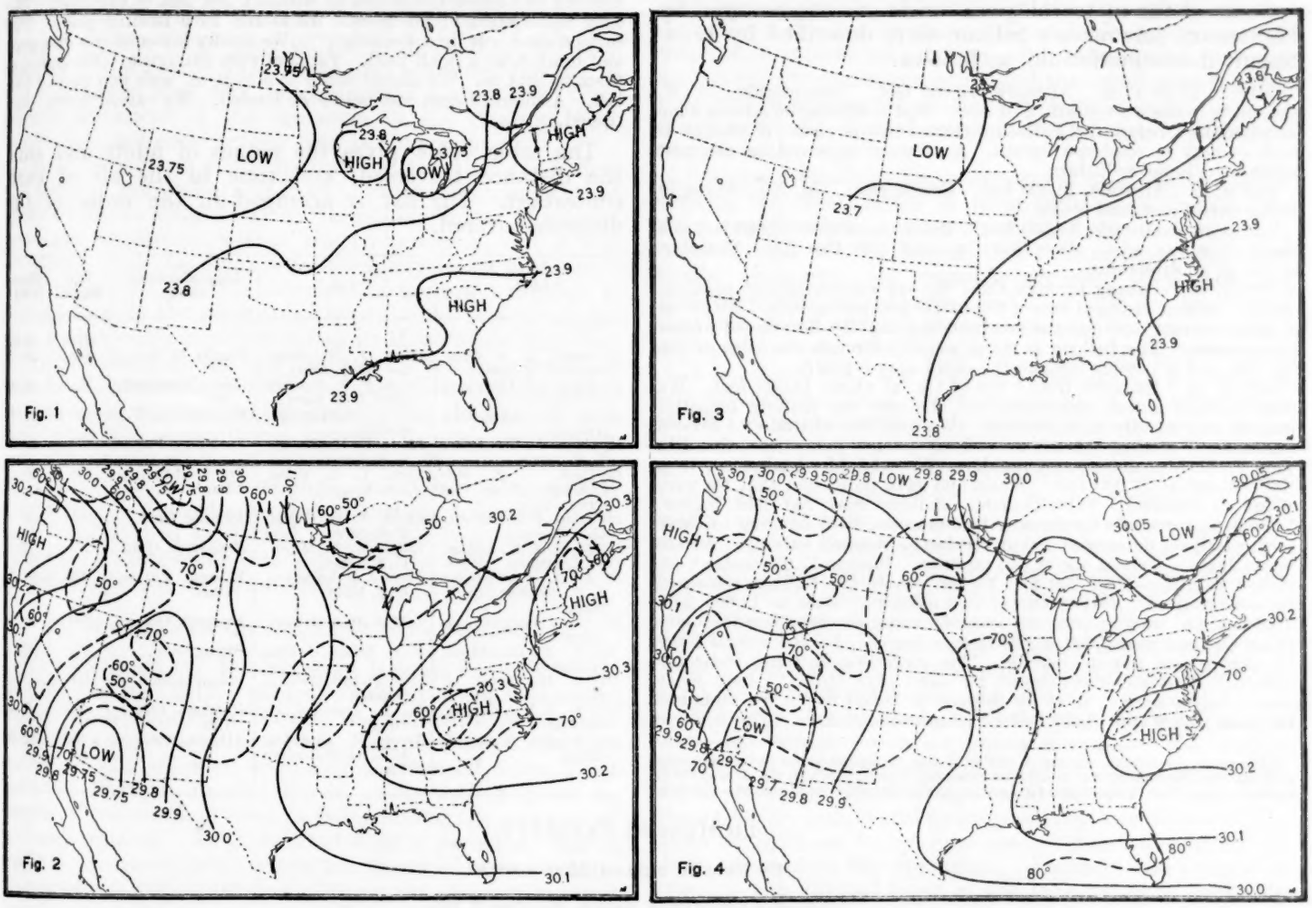
A distinct feature of the free-air conditions at this time and one gratefully welcomed by the balloonists was the continuation of moderate westerly winds at altitudes of 1,000 meters and higher, a result, undoubtedly, of the relatively lower temperatures over the Hudson Bay region. An interesting incident of the race indicating the steadiness with which the general wind drift continued was the sighting of four other balloons by Lieutenant Lawrence very close to his own after more than 12 hours in the air. After 23 hours he again sighted one of the

[1] Meisinger, C. Le Roy: MO. WEATHER REV. SUPP. NO. 21. The preparation and significance of free-air pressure maps for the central and eastern United States.

other balloons about 10 miles distant. On the 3d there was apparent on the 2,000-meter pressure chart, Figure 1, a shallow depression over the lower Lakes region. A depression was subsequently found over Ontario on the surface weather map of the 4th, Figure 4. The free-air pressure charts, while being an entirely new feature in this work, were found most helpful and profitable. They conveyed graphically, in a striking manner, the general pressure gradients at these critical altitudes. It is thought that these charts should be made a permanent part of the meteorological contribution in all future events of this character.

Intermittent showers set in at Indianapolis during the afternoon of the 3d and continued until nearly noon of the 4th. This made inflation somewhat unpleasant, but fortunately no gusty winds occurred, thereby allowing this process to proceed without any serious mishaps.

The balloons took off beneath an overcast sky and drifted north-northeastward in a very light wind, remaining low until they were lost to view of the spectators at the field. Practically all of the balloons encountered thunderstorms during their voyage and owing to these they were finally forced to land. Lieutenant Lawrence observed a temperature lapse rate at an altitude of 3,000 feet, which exceeded the adiabatic rate for dry air, indicating the favorable conditions for thunderstorm development. Strong ascending and descending currents were frequently experienced by all the contestants and considerable difficulty resulted in maintaining constant altitudes. A tragic casualty marred this year's race in the death of the two naval officers, Lieut. L. J. Roth, pilot, and Lieut. T. B. Null, aid. Both were drowned in Lake Erie after a forced landing caused by a defective valve. Numerous other less serious accidents occurred to several of the other contestants, due mostly to thunderstorms and in some instances to mechanical defects. Some of the more thrilling escapes from accidents in forced landings are briefly described in the following accounts. The first refers to Upson and Andrus.



FIGS. 1-4.—Pressure maps at sea level, and 2,000 meters above sea level, at 8 a. m., seventy-fifth meridian time, July 3 and 4, 1923. At left, July 3; at right, July 4. Surface maps, below; free-air maps, above.

Balloon split at 5,800 feet, forcing us to descend, using balloon as a parachute.

The following report came from Donaldson:

Landed 6.12 a. m. July 5, 8 miles northeast of Bryan, Ohio; impossible to rip, was compelled to jump, allowing balloon to escape.

The following was taken from the log of Van Orman:

Balloon seemed to be leaking badly, and after sunset it was evident we would soon run out of ballast. All disposable equipment was thrown over and one-half bag ballast saved for landing, which was made in absolute darkness with drag rope. Landing made with help of farmer who pulled balloon out of trees.

Norfleet reported as follows, after being compelled to descend to a low altitude, owing to thunderstorms:

* * * In dragging across a large oak tree the drag rope became wound around a limb two or three times. I was about to cut it away when I attracted the attention of some people and asked them to release it or cut it at the tree. They were proceeding to do this when a

gust of wind of about 25 miles an hour struck the balloon forcing it down into another tree, at which time the rip cord became entangled in the branches of this tree, pulling it loose from the basket. This forced me to land at once and ended the race so far as this balloon was concerned.

The following is taken from McCullough's log:

Forced to ground by being caught in two thunderstorms while over Coraopolis, Pa., one from the northeast and one from the southeast. Terrific winds which drove the balloon almost due west and requiring a rip landing at Frankfurt Springs, Pa.

Some of the meteorological conditions encountered by Lieutenant Lawrence's balloon were described by Lieutenant Reichelderfer aid, as follows:

July 5, 11.20 a. m. Altitude, 13,400 feet. Temperature, 45° F. Cu. rising to the west, north, and east. Mist is forming on a level some hundred feet below the balloon. Our course is east. Humidity is high enough to condense breath. A rainbow appeared on the mist around the balloon shadow.

2.30 p. m. Altitude, 14,500 feet. Course east. Cu. Nb. closing in to the north, east, and south.

2.35 p. m. Altitude, 14,300 feet. Below us at about 9,000 feet is a thick Cumulus mist. Sky: 5/10 Cu. and 4/10 Cu. Nb. Thunderstorms in all directions.

4.05 p. m. Passing through Cu. We are valving almost continuously. Balloon rising at rate of 600 to 800 feet per minute. We are in a rising current and our gas is expanding rapidly because of higher temperature. The balloon is rising rapidly through the edge of the Cu. Nb. and is passing through the cloud very rapidly.

4.10 p. m. Emerged from [2] top of Cu. at about 14,000 feet. We were valving almost continuously. The sun was shining brightly. Balloon rose rapidly to 16,500 feet. We held this altitude for several minutes. Towering Cu. all around us. Some below us. Cu. Nb. were on all sides and growing rapidly. We valved for a minute or two. Balloon rose to 17,000 feet. Statiscope gave indication that we were about to descend. Valved more. Balloon rose 200 feet higher. Valved continuously for three or four minutes, both hanging to valve cord. Balloon descended 100 or 200 feet. Stopped valving. Ascent began again. Valved one or two minutes. Rose to 17,600 feet. Continued valving. Rose 200 feet higher, where the balloon remained for a short time. Valved one or two minutes. Rose to 18,000 feet. The Cu. Nb. were growing all around us and thunder was frequent. Other Cu. tops were 2,000 or 3,000 feet below us. Valved several times for one or two minute periods. The statiscope at times indicated descent. This never continued for more than 50 or 75 feet, when ascent began again. Rose by degrees to 18,500 feet. We remained between 18,500 and 18,000 feet for 30 minutes or more. The flotation bags burst one after another with loud reports. We valved for two or three minute periods (as long as the two of us could hang on to the valve cord) six to ten times. Cu. tops were all around us. There was frequent thunder. There were some Cu. tops below us some 3,000 or 4,000 feet. Finally, after many minutes of valving, descent began slowly. Reached top of clouds at about 14,000 feet. Descended rapidly through clouds for several thousand feet at rate of 1,000 or 1,200 feet per minute. Began expending ballast including the helium bottle. Came out of base of clouds at about 7,000 feet. Mountains were all around, a town or two, and a railroad. There were occasional cleared fields and a great deal of woodland. Descended rapidly to 500 feet. Dumped over ballast as balloon neared ground. Drag rope touched as balloon descended to within a few feet of the trees. The drag rope caught in the trees. We looked for a landing place. The surface wind was light westerly (?) We finally loosened the drag rope and headed for a small field. Farmers were gathering. We called to them to hold us. We landed easily at 5.55 p. m. with two bags of ballast. A shower began just before we landed. We valved down, then ripped.

[2] The nearly continuous valving as recited in this paragraph seems to be conclusive evidence that the balloon was in a strong ascending current in which the air was rising en masse rather than in discontinuous shreds as has sometimes been suggested.—EDITOR.

The table below gives the names of pilots and aids, the distance traversed, and time in the air of each contestant. The list is arranged in the order of the distance covered.

Pilot.	Aid	Landed (nearest town).	Distance.	Time in air.
			Miles.	*H. m.*
(1) Lieut. R. S. Olmstead, U. S. Army.	Lieut. J. W. Shoptaw, U. S. Army.	Marilla, N. Y.....	449.5	28 15
(2) Lieut. J. B. Lawrence, U. S. Navy.	Lieut. F. W. Reichelderfer, U. S. Navy.	Glen Campbell, Pa.	398.1	25 42
(3) H. E. Honeywell, civilian.	P. J. McCullough, civilian.	Brockton, N. Y...	397.2	28 11
(4) Capt. L. T. Miller, U. S. Army.	Lieut. C. M. Brown, U. S. Army.	Ford City, Pa.....	370.0	23 31
(5) Capt. C. E. McCullough, Officers' Reserve Corps.	Lieut. C. R. Bond, U. S. Army.	Frankfurt Springs, Pa.	312	20 4
(6) Lieut. F. B. Culbert, U. S. Navy.	Lieut. T. D. Guinn, U. S. Navy.	Alliance, Ohio....	284	20 6
(7) Lieut. J. B. Jordan, U. S. Army.	Lieut. M. F. Moyer, U. S. Army.	Macedonia, Ohio..	272	(?)
(8) Lieut. Commander J. P. Norfleet, U. S. Navy.	Lieut. J. B. Anderson, U. S. Navy.	Mount Eaton, Ohio.	250	18 28
(9) J. A. Boettner, civilian.	J. M. Yolton, civilian..	Fremont, Ohio....	199	16 10
(10) R. F. Donaldson, civilian.	P. A. Erlach, civilian.	Bryan, Ohio.....	157	(?)
(11) R. H. Upson, civilian.	C. G. Andrus, Weather Bureau.	Wapakoneta, Ohio	118	(?)
(12) W. T. Van Orman, civilian.	H. V. Thadden, civilian.	Hartford City, Ind.	68	5 40
(13) Warren Rasor, civilian.	Lieut. R. Emerson, U. S. Naval Reserve Force.	Atlanta, Ind.....	30	2 50

LIGHTNING FATALITY.

By ERIC R. MILLER, Meteorologist.

[Weather Bureau Office, Madison, Wis., June 27, 1923.[

On Monday, June 18, 1923, two instructors in the University of Wisconsin, W. E. Armentrout and M. L. MacQueen, were struck by lightning while crossing an open lot used by the university for the storage of coal. Armentrout was instantly killed, but MacQueen is now recovering, and I have obtained the following information from him:

He was conscious throughout the period of the electrical discharge and realized that he was being struck by lightning. He says that the pain of the spasmodic contractions of his muscles was terrible, but the noise and heat of the flash were nearly as bad. He speaks also of a sensation of terrible pressure on his head.

The current entered his body at his left shoulder, which is seared over an area of about 4 inches. The muscles of his legs near the ankles were wrenched by the spasmodic contractions and were swelled so that his leg at that point was about twice the normal size when I saw him. He was paralyzed from the waist down for a few hours after the flash.

Armentrout, who was killed, was also burned on his left shoulder and arm, and a small patch of hair was burned from his head. MacQueen, who fell beside Armentrout, says that he tried to rouse Armentrout and noticed that as he did so Armentrout turned blue. Doctors tell me that this cyanosis indicated that Armentrout's heart had stopped, probably as a result of severe tetanus due to the passage of electricity through the muscle of the heart.

The place where these men was struck is a very low place, and ground water is not far below the surface. Three holes remain to show where the lightning entered the ground. That iron has little directive effect on lightning is shown by the fact that a railroad rail lay about 10 feet away, the track of a railway switch about 30 feet away, a crane 100 feet away, and wire fences and the buildings of the Forest Products Laboratory about 150 feet away. The cloud, which came from the southwest, had passed over houses, trees, and an iron smokestack within a few hundred yards.

NOTES, ABSTRACTS, AND REVIEWS.

FORECASTING MONSOON RAINFALL IN INDIA.

[Reprinted from *Nature*, London, August 4, 1923, p. 175.]

A memorandum regarding the probable amount of monsoon rainfall in 1923 was submitted in the early part of June to the Government of India by Mr. J. H. Field, officiating Director General of Observatories. For the purpose of a forecast of the monsoon, India is divided into five sections, and the several conditions which are favorable for the various sections are given, the conditions ranging over a large part of the globe and at different seasons of the year. It is noted that a marked feature of the weather in May was the comparative absence of temporary advances of the monsoon in the Arabian Sea, where the monsoon proper was behind time.

Details are given of the influencing conditions in different parts of the globe, and from these it is concluded that there would be some delay in the establishment of normal monsoon conditions within the Indian area, but it was estimated that the delay was not likely to be prolonged. With regard to the total amount of monsoon rainfall, it seemed that in the peninsula there should be a small excess, with a corresponding excess in Mysore and Malabar.

For northern India and Burma no forecast could be issued. Recent telegraphic communications from Bombay received in the middle and toward the end of July state that the agricultural outlook is now satisfactory over almost the whole of the Bombay Presidency, where enough, or more than enough, rain has fallen nearly everywhere. According to usual custom, a further monsoon forecast will be issued in August; past experience shows that the earlier forecast issued in June is usually, on the whole, the more successful.

SNOW SURVEYS ON RECLAMATION PROJECTS.

We note from the Reclamation Record for July, 1923, that Mr. Calvin Casteel, project manager of the Okanogan unit of the Reclamation Service, has made for the past six years what appears to have been a simple though effective survey of the snowfall available for run-off from West Fork of Salmon Creek, Wash. The article gives no details of the method used in determining the amount of probable run-off. It is inferred that a personal visit is made to the snow fields where the depth of snow and the proportion of the watershed covered are the factors used in estimating the probable run-off.

Since 1911 the Weather Bureau has been recommending the intensive method of snow surveying.

This method has been applied to several watersheds of relatively small extent[1] and has given satisfactory results.

It is hoped that in the interest of other project managers Mr. Casteel will supply further details of his method of determining the probable run-off from visual inspection of the snow cover on the watershed.—*A. J. H.*

THE AURORAL SPECTRUM AND THE UPPER STRATA OF THE ATMOSPHERE.

By L. VEGARD.

[Abstracted from *Philosophical Magazine*, July, 1923, pp. 193-211.]

The author, in considering recent observations of the auroral spectrum made at the Geophysical Institute of Tromsø together with those made earlier, concludes that most, if not all, of the spectral lines must be due to nitrogen. Of 35 lines measured, 29 may be ascribed definitely to nitrogen, but the remaining 6 offer some difficulties. Two of these are very probably due to nitrogen; the remaining four—of which one is the characteristic green line—can not be ascribed either to hydrogen, helium, or oxygen. An important result of these studies is the failure to find a trace of hydrogen or helium spectra in the high levels of the atmosphere where these two light elements are supposed to occur. Attempts in the laboratory to produce these spectra by means of cathode ray bombardment in mixtures of nitrogen ahd helium and nitrogen and oxygen were unsuccessful, and the conclusion reached was that the pressure of these two gases must be very much less than that of nitrogen in the region of auroral occurrence.

Various difficulties are propounded and discussed concerning the distribution of these light gases in the topmost region of the atmosphere, and the conclusion is reached that the hydrogen and helium layer does not exist. Moreover, the possible presence of a new gas (geocoronium) is dismissed. This lends to the belief that the green auroral line is due to nitrogen and that nitrogen exists to the very limit of the atmosphere.

It is found that the nitrogen pressure at a height of 400 kilometers under the assumption of a temperature of 220° A. is the same as that for 542 kilometers with an assumed temperature of 300° A. Both of these levels are within the region of auroral occurrence, hence the higher temperature demanded by the recent study of Lindemann and Dobson on meteors, (see abstract below), does not alter the conclusions concerning the extremely low nitrogen pressure. In order to produce the observed light intensity at those levels the density of electric radiation must be enormous; indeed, this leads to a value of radiation intensity so great that it could not occur. Therefore, in some way, the nitrogen pressure must be greater than that calculated.

Owing to the photoelectric effect of the sun's action upon the upper layers of the atmosphere, the author believes that a layer of positive ions must exist which would give the effect of increased density. Thus light gases such as helium and hydrogen when ionized would become so light as to fly into space, thus accounting for their absence in the spectrum. Further, the failure to produce the auroral lines in the laboratory is probably due to the inability to reproduce the high degree of positive ionization in the gas. This would solve the problem of Lindemann and Dobson, and make unnecessary the assumption of improbable temperatures in the high atmosphere.

A footnote, inserted in the proof, states that since preparing the manuscript for his article the author has found that the highly ionized upper layer of nitrogen can not exist in the form of a gas, but is probably produced by the charge being carried by crystals of nitrogen. This renders some modification of the mathematical considerations necessary—a matter that will be dealt with in a second paper.—*C. L. M.*

THE CHARACTERISTICS OF THE ATMOSPHERE UP TO 200 KILOMETERS AS INDICATED BY OBSERVATIONS OF METEORS.

By G. M. B. DOBSON.

[Abstr. from *Quart. Jour. Roy. Met. Soc.*, July, 1923, 49: 152-165, 6 figs.]

The increasing use of meteors in meteorology is a welcome development. Kites and balloons, during the past quarter century, have given us a fairly accurate

[1] Henry, A. J. The density of snow, MO. WEATHER REV., March, 1917, 45; 102-107.

knowledge of the atmosphere up to 20 km. Beyond 25 or 30 km. we have little prospect of direct observations, but various luminous phenomena, especially meteors and auroras, offer excellent opportunities for making deductions. The body of observations of meteors, particularly as to velocities, heights of appearance and disappearance, lengths of paths, and luminosities, is sufficient to allow the computation of sizes of meteors, densities of the air traversed, and, with other aids, probable temperatures and compositions of the atmosphere to a height of 200 km. Most meteors seem to have a size of the order of 1 mm. in diameter. Yet at their speeds of from under 15 to over 100 km. per second they so compress the air in their paths that it is heated to a degree high enough (2,000–4,000 A) to volatize at least the surface material of the meteor and to render it highly luminous.

The density of the air required to produce this effect must be 10 to 100 or more times greater than that computed by assuming that the temperature above 20 km. is the same as at that height. At 100 km. meteors seem to indicate a density of 0.00000001 gm. per cc. [cf. 0.001293 gm./cc. at standard sea-level conditions]. This greater than assumed density must be largely owing to higher temperatures and, therefore, more expanded and elevated layers of air.

It seems probable that the temperatures observed in the stratosphere, about 220 A (163° F.) obtain up to a height of 50 km., while from 60 to 160 km. the temperatures are about 300 A (81° F.). Above 200 km. the temperature may again be 220 A. The warmth of the layer from, say, 60 to 160 km., is ascribed to an absorptive layer of ozone, formed, presumably, by the action of the ultra-violet light on such oxygen as is present in the upper portion of the atmosphere. The absorption of ultra-violet radiation here appears to be responsible for the fact that only one twenty-thousandth part of the ultra-violet (wave length 2,900 Ångströms), probably coming from the sun, reaches the earth's surface in clear weather.

The solar heat absorbed in the ozone layer is perhaps 5 per cent of the total reaching the outer atmosphere. There appears to be a marked change in temperature from winter to summer, with a corresponding higher air density, and therefore higher limits at which meteors disappear in summer than in winter. A similar seasonal change in the height of the aurora will be looked for. The presumption of a change in temperature between 50 and 60 km. is strengthened by the marked infrequency with which meteors cross from the warm into the cold layer without fading out and the occurrence of luminosity with meteors at apparently lower velocities in the lower part of the warm than in the upper part of the cold layer. Furthermore, the well-known occurrence of a zone of sound outside a zone of silence about a great explosion could be explained by the presence of a warm layer beginning at a height of about 60 km.

The meteor observations do not support an assumption of the predominance of hydrogen at the heights where meteors occur. As in the lower atmosphere, the air seems to be predominantly nitrogen up to 160 km. Above this some rather doubtful observations indicate the presence of a lighter gas, probably helium, if, as seems likely, hydrogen is negligible.—*C. F. B.*

EFFECT OF CLIMATIC CONDITIONS ON FRUIT TREES.[1]

By Prof. H. A. PHILLIPS.

Author's summary.

(1) While many factors, such as available food, abundant water supply, pruning, spraying, and tillage, contribute to successful orcharding, there is none of more relative importance than climatic conditions.

(2) Epochs in fruit-bearing trees are retarded in their development by an increase in altitude. According to the data the average retardation is one day for every 101 feet.

(3) The average rate retardation in the blooming period of fruit-bearing trees is 4.6 days for every degree of increase in latitude. The greatest retardation is through the Atlantic States, and the least through the Pacific States.

(4) Epochs are earlier westward, and the lines of full-bloom dates and the ripening dates travel in a northeast direction.

(5) In the Atlantic and the Mississippi sections the rate of retardation is not constant. This is explained by conditions affecting the rest period. From the thirty-sixth parallel southward in the Mississippi Valley and the thirty-eighth parallel southward in the Atlantic section there is very little difference in the time of the blooming period.

(6) There is much greater uniformity in the epochs in fruit-bearing trees through the Pacific States, due primarily to the influence of the prevailing westerly winds from the Pacific Ocean.

(7) The ripening dates along any section travel faster than the blooming dates.

(8) The general average range of full-bloom dates at any given place is about three weeks.

(9) The number of days for the development of the ripened fruit is greater in the Pacific section than in the Atlantic and the Mississippi sections. Also the number is greater in the southern part of the Atlantic and the Mississippi sections than in the northern part.

(10) The peach, wherever grown, appears to be more uniform in its development than the other fruits.[2]

WEATHER AND CORN WILT.

Corn wilt, known as Stewart's disease, has been found in a large number of States, both in the South and the North. In the fields where found the number of diseased plants has been usually less than 20 per cent, but as high as 100 per cent infection has occasionally been found among the earlier varieties.

Dr. F. V. Rand, pathologist, and Miss Lillian C. Cash, scientific assistant, United States Department of Agriculture, have conducted field studies of this disease in Maryland during three seasons. A short account of results was published in the *Journal of Agricultural Research*, Vol. XXI, No. 4, May, 1921.

Varietal influence was found to be considerable, the earlier varieties being much more susceptible to the

[1] Author's thesis: Effect of climatic conditions on fruit trees in relation to the blooming and the ripening dates and the length of the growing period.

[2] The same data used by Doctor Phillips were partially summarized and presented in maps and tabular form in "Graphical summary of seasonal work on farm crops," by O. E. Baker, C. F. Brooks, and R. G. Hainsworth in Department of Agriculture Yearbook, 1917.

disease than those maturing later. Rich soil was also favorable for disease development. In addition, infection of the young plants from the seed was found to be largely dependent upon the weather during the first four weeks of growth, moisture exerting the greater influence. When rain was plentiful about the time of seeding, wilt later developed in abundance, whereas the same kind of seed planted during dry periods invariably gave less infection. With moisture conditions approximately the same, the later plantings, at higher temperatures, gave the greater amount of wilt.

From the experiments it seemed apparent that anything which retarded the germination and early development of the seedlings lessened the chance of infection from the seed. Of the environmental factors, soil moisture and temperature seemed to have the greatest influence.—*J. B. K.*

RADIATION AND THE TEMPERATURE OF SNOW AND CONVECTION OF THE AIR AT ITS SURFACE.[1]

By A. ÅNGSTRÖM.

[Reprinted from *Science Abstracts*, Aug. 31, 1921, p. 549.]

Observations of snow and air temperature and of radiation at Abisko (68° 21′ N., 18° 47′ E.) during the "arctic night," January, 1916, are utilized to evaluate the "convectivity" (k) of the air near the snow surface. The actual elements observed included (1) the effective radiation (R) by Angström pyrgeometer exposed about 2 m. above the snow surface, (2) the temperature (t_2) of the air at this level, (3) the temperature (t_1) of the air 0.6 m. above the surface, (4) the snow surface temperature (t_0), (5) the snow temperature (t_s) 1.8 cm. below the surface. (1) is reduced to the effective radiation (R_0) of the snow surface by the relation

$$R_0/R = (273+t_s)^4/(273+t_2)^4,$$

the emissivity of snow for long waves being practically unity, while from t_0, t_1, and t_s are deduced the vertical temperature gradients at the surface, both in the snow and in the air. Now, considering the time of observation, direct and diffuse solar radiation are eliminated, while exchanges of heat due to condensation and evaporation at the surface are found to be of relatively small importance, and the temperature variations sufficiently slow to allow the surface to be treated as in temperature equilibrium. Accordingly $R_0 = k(\partial t/\partial h)_{air} - \lambda(\partial t/\partial h)_{snow}$. Selecting cases in which $(\partial t/\partial h)_{snow}$ is zero or small, an approximate average of k is deduced from $R_0 = k(\partial t/\partial h)_{air}$ and this, when inserted in the previous formula, yields a value of $\lambda = 0.00049$, in good agreement with the value 0.0005 deduced from Abel's formula $\lambda = 0.0068\rho^2$ or the value 0.00059 from Jansson's formula $\lambda = 000005 + 0.0019\rho + 0.006\rho^4$, where ρ is the density of the snow. Adopting this value of λ, and utilizing all observations, the average value of k then becomes 1.8. These values of λ and k apply when R is measured in gm. cals. cm.$^{-2}$ min.$^{-1}$, and the thermal gradients in deg. C. cm.$^{-1}$. Individual values of k vary with the wind speed near the surface. In the cases considered, this averaged 2.8 m. sec.$^{-1}$ as measured by anemometer 15 m. above ground.—*M. A. G.*

[1] Ark. f. Mat., Astron. och Fysik. 13. No. 21, pp. 1-18, 1919.

HIGH DAY TEMPERATURES IN EUROPE IN JULY.

Press dispatches and excerpts from English newspapers indicate that exceptionally high day temperatures were prevalent during the second week of July in the British Isles as well as in northern and western portions of the Continent. Many heat prostrations and much suffering was recorded. A thunderstorm during the early morning of July 10 in London was featured as being unusually severe.—*A. J. H.*

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C. FITZHUGH TALMAN, Meteorologist in Charge of Library.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1923.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for April, 1920, **48**:225, and a note in the REVIEW for November, 1922, **50**:595.

From table 1 it is seen that direct solar-radiation intensities averaged decidedly below the normal values for July at Washington, D. C., and close to normal at Madison, Wis., and Lincoln, Nebr.

Table 2 shows that about the average amount of solar and sky radiation for July was received on a horizontal surface at all three stations.

Skylight-polarization measurements, obtained at Washington on four days give a mean of 51 per cent, with a maximum of 59 per cent on the 23d. At Madison measurements obtained on four days give a mean of 59 per cent, with a maximum of 61 per cent on the 18th. These are slightly below average values for July at Madison, and close to July averages for Washington.

TABLE 1.—*Solar radiation intensities during July, 1923.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.0°	75.7°	78.7°	Noon.
	75th mer. time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
July 3	11.38	.....	.....	.....	0.93	.....	.....	.....	.....	.....	13.13
5	16.79	.....	.....	.....	0.85	1.06	.....	.....	.....	.....	14.60
17	14.60	.....	.....	.....	0.81	0.97	.....	.....	.....	.....	10.97
18	13.13	.....	.....	.....	0.59	.....	.....	.....	.....	.....	10.21
19	10.59	.....	0.49	.....	.....	1.11	.....	.....	.....	.....	10.21
20	14.60	.....	.....	0.44	0.66	1.05	.....	.....	.....	.....	13.61
21	12.68	.....	.....	0.38	0.82	1.12	.....	.....	.....	.....	9.83
23	7.87	.....	.....	.....	1.02	1.40	.....	.....	.....	.....	6.76
25	17.37	.....	.....	.....	.....	1.14	.....	.....	.....	.....	12.68
26	10.59	.....	.....	0.64	0.81	1.26	1.07	0.89	0.75	.....	9.14
Means	.....	.....	(0.49)	0.49	0.81	1.14	(1.07)	(0.89)	(0.75)	.....	.....
Departures	.....	.....	−0.19	−0.30	−0.09	−0.05	+0.10	+0.12	+0.09	.....	.....

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during July, 1923*—Continued.

Madison, Wis.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.0°	75.7°	78.7°	Noon.
	75th mer. time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
July 12	11.81	.....	0.76	0.85	1.07	1.32	.....	.....	.....	.....	11.38
17	9.47	.....	.....	.....	1.09	1.41	.....	.....	.....	.....	8.81
18	10.59	.....	.....	.....	1.05	1.35	.....	.....	.....	.....	10.59
24	16.20	.....	.....	.....	1.04	.....	.....	.....	.....	.....	14.10
25	12.68	.....	.....	0.92	1.05	.....	.....	.....	.....	.....	9.47
Means	.....	.....	(0.76)	(0.88)	1.06	1.36	.....	.....	.....	.....	.....
Departures	.....	.....	±0.00	−0.01	+0.03	+0.10	.....	.....	.....	.....	.....

Lincoln, Nebr.

July 8	16.20	.....	.....	.....	1.11	1.29	.....	.....	.....	.....	12.68
9	17.37	.....	0.78	0.93	1.10	1.33	.....	.....	.....	.....	13.11
14	18.59	.....	.....	0.71	0.93	1.17	.....	.....	.....	.....	16.20
28	9.83	.....	.....	0.91	1.20	1.44	.....	.....	.....	.....	9.14
30	12.68	.....	.....	.....	1.13	1.39	.....	.....	.....	.....	14.60
31	14.60	.....	0.70	0.83	1.01	1.28	1.14	0.93	0.80	.....	12.68
Means	.....	.....	(0.74)	0.84	1.08	1.32	(1.14)	(0.93)	(0.80)	.....	.....
Departures	.....	.....	−0.06	−0.06	±0.00	−0.01	+0.07	+0.04	+0.05	.....	.....

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 2	526	476	631	+16	−62	+55	−1,989	+927	−68
9	458	515	514	−39	−16	−67	−2,263	+818	−534
16	521	598	604	+37	+85	+33	−2,003	+1,416	−303
23	467	419	490	−6	−72	−60	−2,044	+913	−721

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The distribution of the average pressure for the month of July, 1923, as determined by observations taken at land stations on the coast and islands of the North Atlantic Ocean, was comparatively uniform, differing but slightly from the normal. The following figures show the average pressure at Greenwich Mean Noon, with approximate departures at a number of selected land stations. The barometric readings are in inches, and the normals were taken from the Pilot Chart.

St. Johns, Newfoundland, average 29.91, departure −0.06. Halifax, N. S., 29.98, +0.04. Nantucket, 30.01, +0.04. Hatteras, 30.01, −0.01. New Orleans, 30.02, +0.02. Turks Island, 30.10, +0.09. Bermuda, 30.20, +0.09. Horta, Azores, 30.33, +0.07. Swan Island, 29.92, +0.00. Lerwick, Shetland Islands, 29.85, +0.05. Valentia, Ireland, 29.99, +0.01. London, 30.01, +0.03.

According to the Pilot Chart, July is normally the quietest month of the year over the North Atlantic, and during the month under discussion winds of gale force were not reported on more than one day in any 5-degree square, with the following exceptions: Square between latitude 40° to 45°, longitude 55° to 60°, where they occurred on four days, the greatest number observed. Squares in latitude 30° to 35°, longitude 75° to 80°; latitude 40° to 45°, longitude 50° to 55°; latitude 50° to 55°, longitude 15° to 20°, where they were reported on two days.

Fog was unusually prevalent during the month and was reported on 20 days in the 5-degree square between latitude 40° to 45°, longitude 65° to 70°; it was reported on 16 days in the square immediately to the eastward and on 15 days between latitude 40° to 45°, longitude 45° to 50°. Fog was also more frequent than usual over the middle section of the steamer lanes and off the coast of Europe.

According to reports received, the weather during the first seven days of the month was comparatively featureless, with light to moderate winds over the entire ocean, although fog was unusually frequent. Charts VIII and IX show the conditions on the 8th and 9th, respectively, when an area of low pressure surrounded Newfoundland, with moderate gales in the southerly quadrants, as shown by the following storm logs.

British S. S. *Galtymore:*

Gale began on the 8th, wind SE. Lowest barometer 29.58 inches at 9.30 a. m. on the 8th, wind S., 7, in latitude 43° 45′ N., longitude 50° 25′ W. End on the 8th, wind S. Highest force of wind 8; shifts not given.

American S. S. *Hera:*

Gale began on the 9th, wind SW. Lowest barometer 29.97 inches at 4 a. m. on the 9th, wind SW., 5, in latitude 36° N., longitude 52° 40′ W. End on the 9th, wind N. Highest force of wind 7; shifts SW.–N.

On the 9th there was a second LOW central near latitude 51° N., longitude 18° W., and northwesterly gales prevailed over a limited area between the 15th and 25th meridians. Storm log:

British S. S. *Baltic:*

Gale began on the 9th, wind W. Lowest barometer 29.60 inches at 5.30 a. m. on the 9th, wind W., in latitude 50° 23′ N., longitude 17° 23′ W. End on the 9th, wind WNW. Highest force of wind 8; steady W.

While the Greenwich mean noon observations on the 9th show moderate conditions off the coasts of South Carolina and Georgia, one vessel a short distance east of Charleston reported a moderate gale that developed later in the day. Storm log:

American S. S. *Virginia:*

Gale began on the 9th, wind E. Lowest barometer 29.91 inches on the 9th, wind E., 6, in latitude 31° 40′ N., longitude 78° 50′ W. End on the 10th, wind NE. Highest force of wind 7; shifts NW–E.

From the 10th to the 16th another period of inactivity ensued, although a few vessels in widely scattered localities reported moderate gales without rendering storm logs.

On the 17th a moderate disturbance appeared central near latitude 45° N., longitude 57° W., with southwesterly gales over the region between the 40th and 45th parallels and 55th and 60th meridians. Storm log:

Danish S. S. *Virginia:*

Gale began on the 17th, wind SW. Lowest barometer 29.96 inches at midnight on the 17th, wind SSW., 10, in latitude 41° 30′ N., longitude 56° 20′ W. End on the 18th, wind N. Highest force of wind 10, SW.; shifts SW–N.

During the night of the 16th the Honduran S. S. *Hibueras* experienced a moderate gale as shown by following report:

At 7 p. m. on the 16th, in latitude 33° 10′ N., longitude 73° 30′ W. Barometer 29.97 inches, wind SW., 7. Weather partly cloudy. Heavy sea. At 7 a. m. on the 17th, barometer 29.97 inches. Wind SW., 5. Weather partly cloudy. [State of sea not given.]

On the 18th another moderate disturbance was encountered in the same general locality by the American S. S. *El Rio.* Report follows:

At 7 p. m. on the 18th, in latitude 33° 20′ N., longitude 76° 40′ W. Barometer 29.86 inches, wind NNE., 7. Weather, passing showers. Rough sea.

At 7 a. m. on the 19th, barometer 29.96 inches. Wind E., 5. Weather, passing showers. Rough NE. sea.

On the 20th there was apparently a disturbance somewhere north of Newfoundland, although it was impossible to locate it accurately on account of lack of observations. Storm log:

British S. S. *Kenbane Head:*

Gale began on the 20th, wind W., 8. Lowest barometer 29.19 inches at 4 a. m. on the 20th, wind SW., in latitude 52° 30′ N., longitude 49° W. End on the 21st, wind W. Highest force of wind 9, W.; shifts SW–W.

At Greenwich mean noon on the 21st moderate weather prevailed over the entire ocean, although later in the day the American S. S. *Minnekahda* encountered a moderate gale, as shown by following storm log:

Gale began on the 21st, wind SW. Lowest barometer 29.71 inches at 9 a. m. on the 21st, wind SW., 7, in latitude 40° 25′ W., longitude 59° 58′ W. End on the 21st. Highest force of wind 8; steady SW.

From the 22d to the 28th there was another period of comparatively mild weather, accompanied by considerable fog. On the 29th two fairly well developed areas of low pressure made their appearance. The first was central near Nantucket, and the second surrounded Ireland. By the 30th the center of the western LOW was near Halifax, and that of the eastern somewhere in the North Sea.

At Greenwich mean noon on the 30th vessels a short distance east of Halifax experienced westerly gales, although no storm logs were received. The American S. S. *Coelleda* also reported a westerly gale off the European coast as shown by the following storm log:

Gale began on the 30th, wind W. Lowest barometer 29.49 inches at 7 a. m. on the 30th, wind W., 7, in latitude 50° 58′ N., longitude 12° 30′ W. End at 3 p. m. on the 31st, wind WNW. Highest force of wind 8, WNW.; shifts 2 points to N.

By the 31st the western disturbance had apparently disappeared while northwesterly gales were encountered

near the 50th parallel between the 10th and 20th meridians. Storm log:

American S. S. *Mongolia:*

Gale began on the 31st, wind WNW. Lowest barometer 29.46 inches on the 31st, wind NW. 8, in latitude 49° 28′ N., longitude 13° 30′ W. End on the 31st, wind NW. Highest force of wind 8, NW.; steady from NW.

The American S. S. *Leviathan*, while in mid-ocean reported a moderate gale from noon to midnight on the 31st. Storm log:

Gale began on the 31st, wind NE. Lowest barometer 29.71 inches at 1 p. m. on the 31st, wind NE., 8, in latitude 44° 25′ N., longitude 37° 29′ W. End on the 31st, wind NE. Highest force of wind 8; steady NE.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The unusual activity which characterized the weather of the North Pacific Ocean in June gave place for the most part to typical midsummer conditions in July. Gales in the higher latitudes became infrequent and there was a decrease in the number of typhoons. Fog increased in the regions where it commonly forms in the summer season.

Pressure in the Aleutian area averaged very close to normal, as shown by observations at Dutch Harbor. In July pressure here reaches its highest point for the year, the monthly average of available observations being 30.02 inches as compared with an annual average of 29.76 inches. In the month under consideration pressure was below normal generally throughout the first half of the month and again at the close, with a period of high pressure from the 16th to 26th. The highest reading, 30.40 inches, was recorded on the 21st; the lowest, 29.70, on the 5th. Absolute range 0.70 inch. At Midway Island pressure continued below normal, the deficiency being some 0.09 inch. The normal here for July is 30.10 inches. The highest reading for the month, 30.12, occurred on the 23d; the lowest, 29.80, on the 5th. At Honolulu pressure was approximately normal, or 30.01, for the p. m. observations. The highest reading, 30.07, was recorded on the 7th; the lowest, 29.86, on the 13th. Precipitation at Honolulu was only 0.25 inch, the month being the third driest July on record. This follows the driest June of record, when only 0.17 inch fell. The normal precipitation for July is 1.19 inches; for June, 0.92 inch.

The North Pacific high-pressure area was very constant throughout the month. During the periods of low pressure at Dutch Harbor its center lay between the Hawaiian Islands and the Gulf of Alaska. As pressure rose in mid-ocean on the 16th the anticyclone became elongated, with the major axis lying east and west and the center shifted some 10° to 15° to the westward.

Reports at hand indicate that low pressure prevailed over the waters of the Far East throughout the month.

As the month opened the most important feature of the weather was the typhoon in the China Sea. This storm had appeared on June 27 about 300 miles to the east of southern Luzon and had traversed the northern part of that island on the 29th, doing considerable damage. Its path there inclined to the northward and it entered China, apparently, during the night of July 2–3, eastern time, a few miles west of Macao, where also it was reported to have caused much damage.

On the 2d a depression appeared to the northwestward of Midway Island, whence it moved during the 3d and 4th in a northeasterly direction, increasing somewhat in intensity, and on the evening of the 5th was centered over Dutch Harbor, where the barometer registered 29.70 inches. Vessels in the vicinity reported moderate to fresh gales. Coincident with this depression a disturbance over Japan caused fresh to strong shifting gales in near-by waters.

On the 5th and 6th violent local storms prevailed off the coast of southern Mexico and Guatemala. The following report of these storms has been received from the American S. S. *Ethan Allen*, Capt. W. H. Stanford, San Pedro for Balboa. Second Officer John S. Weldon states that the first indication of these two gales, or squalls, was a gathering of heavy black clouds on the horizon in the direction from which the wind came. These moved very rapidly and when nearly overhead the wind struck. From the time that the clouds first appeared to the time when wind struck was not over 30 minutes, the wind coming in little puffs from all directions. There was no gradual increase in force of wind—it struck with full force. The first gale occurred from 3.30 a. m. to 9 a. m. of the 5th in 14° 17′ N., 94° 10′ W.; the wind direction was ESE. to E. and it attained force 11, E. The lowest barometer, 29.91, corrected, occurred at 4 a. m. This blow was accompanied by thunder and severe lightning, and heavy rain fell at times.

The second gale occurred between 12.40 a. m. and 5 a. m. of the 6th, in 12° 50′ N., 90° 40′ W. The wind blew steadily from ENE., reaching force 12. The lowest barometer was the same as in the preceding storm. There was severe lightning but very little thunder. Light to moderate rain fell throughout.

These sudden, short-lived gales continued until at least the middle of the month. The American S. S. *Charles Pratt*, Capt. Geo. E. Bridgett, also from San Pedro for Balboa, experienced one on the 8th, when between Chamela Bay and Manzanillo; another on the 11th, in 15° 30′ N., 97° 45′ W.; and a third on the 14th beginning at 10° 45′ N., 88° 20′ W. According to the descriptions given by First Officer H. Thorsen, these gales were not so violent as those encountered by the *Ethan Allen*, the wind attaining forces 7, 9, and 8, re-respectively, in the three.

The American S. S. *Ipswich* also reported a severe electrical storm off Acapulco during the night of the 15th, followed by heavy wind and rain squalls.

On the 12th the British S. S. *Eburna*, Capt. D. O. Evans, San Pedro for Yokohama, experienced a southwesterly gale in 33° 58′ N., 165° W., due to a trough-like depression extending from Alaska to the neighborhood of Midway Island. Second Officer H. W. Elgat states:

At 8 a. m. (civil time) experienced a very heavy west swell, wind at times being SSW., gale force. Wind and sea increased toward midday, when the wind attained its highest velocity (10, SSW.). At 2 p. m. wind shifted to SW. and commenced to decrease. At 5 p. m. wind shifted to W. by S., sea and wind decreasing. Midnight, wind W., with heavy westerly swell. Heavy rain squalls throughout. Lowest barometer 29.74 inches, at 8 a. m. of 12th.

On the 20th and 21st moderate to fresh southerly to southeasterly gales were experienced by several ships in mid-ocean. These gales occurred on the western side of the North Pacific HIGH and in the front of a depression that advanced from the region of the Bonin Islands. This depression apparently dissipated on the 22d in the region southeast of Kamchatka.

Reports at hand indicate that during the last week of July a series of depressions moved northeastward over Japan and adjacent waters and also point to the formation

of one or more typhoons in the region of the Philippines. It will be necessary, however, to have additional reports to determine the actual conditions within these areas.

GALE IN SOUTH ATLANTIC OCEAN.

The British S. S. *Vestris*, Capt. O. Penrice, experienced a heavy gale upon leaving Buenos Aires for New York in the early part of July, this year, of which First Officer A. G. T. Brown has furnished the following report:

July 9. Left Buenos Aires at noon. Strong SE. gale with heavy rain; heavily overcast and hazy.

July 10. Breeze falling light, leaving heavy swell (2 a. m.); 3 a. m. to 6 a. m., thick fog patches; 6.30 a. m., wind came from N'ly, increasing steadily and backing slowly; 6 p. m., strong WNW. wind and confused sea; overcast, St. Cu.; bar. 29.41, steady. By midnight, July 10–11, vessel not steering; whole gale from W.–WNW.; huge seas doing considerable damage; constant stream of spray and small seas deluging vessel fore and aft; bar. 29.57, rising slowly.

July 11. 8 a. m. vessel hove to, heading WNW.; wind about W. by S. Noon, similar weather; no apparent moderation; very hazy; bar. 29.81, still rising. 3 p. m. vessel resumed course and speed. 8 p. m. wind and sea moderating rapidly; heavy showers.

July 12. Wind and sea moderating all day; bar. rising steadily; weather fine and clear.

The lowest barometer recorded was 29.29 inches at Buenos Aires. Highest wind, force 10, W. by N. Shifts of wind, SE.–NW.–WNW.–W.–WSW.–SW. by W.

(F. G. T.)

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

By A. J. HENRY.

From a physiological view point the most significant feature of the weather of northeastern United States was the absence of prolonged high temperature or, what amounts to the same thing, the rather frequent occurrence of cool spells due to the movement of anticyclonic areas over from the Hudson Bay region. West of the Appalachians mean temperatures were somewhat higher.

The rainfall was rather irregularly distributed.

The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

Low-pressure areas were numerous, but rather ill-defined and often difficult to trace from day to day. A majority of these depressions were first noted in western Canada. These moved southeastward, and there were frequent secondary formations in middle latitudes; but in no case did they develop storm intensity.

High-pressure areas were fairly numerous, nine of which seemed worthy of tracking; but, on the whole, they were unimportant, except that they gave pleasant alternations to cooler and drier weather, particularly over northern and central districts east of the Mississippi River. Four of these anticyclones were of the Hudson Bay type.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

Free-air temperature departures for July showed practically no change from the surface to 3,000 meters. (See Table 1.) In agreement with Climatological Chart III, the largest positive departures occurred at Ellendale, becoming smaller southward and eastward, and finally negative at Due West. This resulted in the interesting relationship found between the mean temperatures for the 3,000-meter level for the various stations. For example, Ellendale, the northernmost station, has a higher mean temperature for this level than Drexel, which in turn is higher than Broken Arrow, Due West, and Royal Center.

Relative humidity departures were mostly small except in the highest levels where the apparently large departures were the result of fewer observations, and therefore less reliable means.

Vapor-pressure departures were mostly positive. At Ellendale from the surface to 3,000 meters were found the highest mean monthly values for July since the establishment of the station in 1918. The resultant winds at this station (see Table 2) differed considerably from the normal both in velocity and direction. The normal at the surface and lower levels, it will be observed, is extremely light and therefore the corresponding direction carries little significance.

This month, however, the velocities were moderately high and likewise the resultant directions, which had a strong south component were closely related with the positive temperature departures previously referred to. In general the resultant winds at the other stations did not differ greatly from the normals both in direction and velocity. Pilot-balloon observations over the country showed a predominant easterly wind above 5,000 meters south of latitude 35° and a westerly north of this latitude. These upper easterly winds were observed at Groesbeck, extending to the highest level reached, which was 13,000 meters. At Ellendale not a single observation showed easterly winds above 5,000 meters, westerly being found to at least 12,000 meters.

There were apparent on the free-air wind charts during the month occasions when the winds at 4,000 and 5,000 meters showed a decidedly anticyclonic circulation, i. e., northerly over the eastern coast, easterly over the Gulf region, southerly over the Plains States, and westerly over the northern region. From an examination of the maps for these periods there seemed to be a connection between this condition and a warm period at the surface, i. e., there was usually a HIGH over the southeastern part of the country merged with the permanent Atlantic HIGH, a condition favorable for warm weather over the eastern part of the country. Such conditions occurred on the 6th, 9th, 20th, and 22d.

A number of cases occurred where southerly winds were overrun by northerly winds. On these occasions the southerly winds resulted from high pressure to the eastward, and usually between 2,000 and 3,000 meters above a reversal to northerly was found. This condition was characteristic only over that portion of the country east of the Rocky Mountains. The opposite condition, i. e., southerly winds overriding northerly ones

was not to be found over this section but on the other hand was of frequent occurrence at western stations such as Denver, San Francisco, Camp Lewis, Wash., and Rockwell Field, Calif. A predominating south-southwesterly wind was found above these levels over the Pacific coast stations indicating a reversal of the pressure gradient over the Pacific HIGH.

Some extremely deep winds were observed, as follows:

Station.	Date.	Direction.	Altitudes (meters).
Broken Arrow	26	N	1,500 to 18,000.
Drexel	23	NW	Surface to 8,500.
Ellendale	12	WNW	4,500 to 12,500.
Groesbeck	25	ENE	2,000 to 11,000.
Broken Arrow	31	N	3,000 to 13,000.

The exceedingly high velocity for this season of the year of 32 m. p. s. was observed at the level of the stratosphere at Drexel on the 19th and at Broken Arrow on the 31st. The direction on both occasions was north.

A description of the free-air conditions prevailing during the National Elimination Balloon Race held from Indianapolis on the 4th will be found under a separate heading in this REVIEW. (See pp. 356–358.)

The kite flight made at Drexel on the morning of the 20th showed an unusually steep temperature inversion directly above a layer of St. Cu. clouds. The base of these was 2,000 meters above the surface, they being less than 100 meters thick. The temperature rose 6° C. through a 250-meter layer just above these clouds accompanied by a drop in the relative humidity from saturation to 28 per cent. Pressure was high over the eastern half of the country and the lower winds at Drexel were south-southwest, veering to west-southwest at the height of the inversion. The winds above 4,000 meters shifted to north-northeasterly. The velocity decreased to nearly a calm at the altitude of the wind shift, then increased to 17 m. p. s. at 10,000 meters.

An interesting phenomonon was observed at Broken Arrow on the 29th when the kite was being reeled in from above a very thin A. St. veil. In being drawn through this cloud there was visible a dark streak giving the appearance of a rift in the clouds being made by the kite.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during July, 1923.*

TEMPERATURE (°C.).

Altitude.	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
m. s. l. (m.)	Mean.	Departure from 5-yr. mean.	Mean.	Departure from 8-yr. mean.	Mean.	Departure from 3-yr. mean.	Mean.	Departure from 6-yr. mean.	Mean.	Departure from 5-yr. mean.	Mean.	Departure from 6-yr. mean
Surface	26.2	−0.7	25.5	+0.5	26.6	−0.4	23.6	+2.1	26.9	+0.1	25.6	−0.1
250	26.1	−0.7	.....	.....	26.2	−0.5	.....	.....	26.0	+0.1	25.4	−0.1
500	25.2	0.0	25.1	+0.7	23.7	−0.6	23.3	+2.1	24.4	+0.3	23.2	+0.1
750	24.1	+0.4	23.7	+0.7	21.9	−0.6	21.9	+2.0	23.5	+0.5	21.2	+0.1
1,000	22.5	+0.3	22.1	+0.5	20.0	−0.7	20.8	+2.1	22.6	+0.8	19.4	+0.1
1,250	20.7	+0.1	20.5	+0.4	18.0	−0.9	20.0	+2.4	21.3	+0.8	17.9	+0.3
1,500	18.9	0.0	18.7	+0.1	16.4	−0.9	18.8	+2.3	19.7	+0.6	16.3	+0.3
2,000	15.3	−0.3	15.6	+0.1	13.5	−0.7	16.2	+2.3	16.4	+0.1	13.5	+0.3
2,500	12.0	−0.4	12.4	+0.2	11.0	−0.2	13.1	+2.1	13.4	0.0	10.3	−0.2
3,000	8.3	−0.9	9.5	+0.7	8.2	0.0	9.9	+1.9	.....	.....	7.3	−0.3
3,500	4.6	−1.5	6.7	+1.4	5.5	+0.5	7.2	+2.3	.....	.....	5.6	+0.9
4,000	.....	.....	3.7	+1.6	.....	.....	4.1	+1.8	.....	.....	.....	.....
4,500	.....	.....	0.5	+1.6	.....	.....	0.4	+0.6	.....	.....	.....	.....
5,000	.....	.....	−2.9	+0.7	.....	.....	−3.0	+0.2	.....	.....	.....	.....

RELATIVE HUMIDITY (%).

Surface	71	+2	65	0	64	−3	75	+4	69	−6	64	+3
250	71	+2	.....	.....	64	−3	.....	.....	71	−5	64	+3
500	67	+1	63	0	65	−3	74	+4	72	−4	64	+1
750	65	0	59	−1	66	−3	71	+6	68	−3	66	+1
1,000	66	+1	58	−1	67	−4	68	+5	64	−3	68	+2
1,250	68	+3	59	+1	69	−3	64	+3	63	−2	67	+1
1,500	70	+5	62	+4	67	−3	61	+3	65	+1	67	+1
2,000	72	+10	62	+6	63	−5	55	0	67	+5	63	+1
2,500	72	+13	60	+6	62	−6	55	+2	69	+8	62	+7
3,000	76	+19	57	+5	61	−6	54	+2	.....	.....	62	+11
3,500	84	+28	50	−2	59	−3	50	−3	.....	.....	33	−13
4,000	.....	.....	54	+4	.....	.....	51	−3	.....	.....	.....	.....
4,500	.....	.....	56	+4	.....	.....	62	+2	.....	.....	.....	.....
5,000	.....	.....	55	+8	.....	.....	62	+4	.....	.....	.....	.....

VAPOR PRESSURE (*mb.*).

Surface	24.00	−0.39	20.99	+0.80	21.91	−1.69	21.79	+3.71	23.99	−1.95	20.76	+0.98
250	23.85	−0.32	.....	.....	21.56	−1.64	.....	.....	23.38	−1.54	20.54	+1.00
500	21.35	+0.21	19.71	+0.55	19.10	−1.46	21.14	+3.65	21.60	−0.85	18.08	+0.66
750	19.35	+0.46	17.06	+0.16	17.42	−1.46	18.58	+3.55	19.27	−0.28	16.56	+0.84
1,000	17.79	+0.60	15.31	−0.01	15.95	−1.46	16.56	+3.13	17.05	−0.14	15.38	+1.02
1,250	16.47	+0.85	14.21	+0.30	14.58	−1.38	14.75	+2.76	15.47	+0.07	13.87	+0.94
1,500	15.11	+1.08	13.40	+0.85	12.86	−1.26	13.02	+2.45	14.59	+0.61	12.57	+0.97
2,000	11.88	+0.86	11.18	+1.17	9.99	−1.40	9.88	+1.43	12.51	+0.94	9.97	+1.14
2,500	9.65	+1.00	8.88	+0.97	8.26	−1.02	8.19	+1.25	10.93	+1.47	7.81	+1.43
3,000	8.33	+1.61	6.94	+0.81	6.83	−0.71	6.61	+0.97	.....	.....	6.35	+1.47
3,500	7.79	+2.36	5.21	+0.39	5.09	−0.33	5.01	+0.27	.....	.....	2.90	−0.75
4,000	.....	.....	5.13	+1.35	.....	.....	4.23	+0.29	.....	.....	.....	.....
4,500	.....	.....	4.65	+1.51	.....	.....	4.07	+0.27	.....	.....	.....	.....
5,000	.....	.....	3.83	+1.45	.....	.....	3.93	+0.49	.....	.....	.....	.....

TABLE 2.—*Free-air resultant winds (m. p. s.) during July, 1923.*

Altitude, m. s. l. (m).	Broken Arrow, Okla. (233 m.)				Drexel, Nebr. (396 m.)				Due West, S. C. (217 m.)				Ellendale, N. Dak. (444 m.)				Groesbeck, Tex. (141 m.)				Royal Center, Ind. (225 m.)			
	Mean.		5-year mean.		Mean.		8-year mean.		Mean.		3-year mean.		Mean.		6-year mean.		Mean.		5-year mean.		Mean.		6-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 19° E.	2.3	S. 1° E.	3.0	S. 3°W.	2.8	S. 1°W.	2.3	S. 20°W.	0.4	S. 58°W.	1.5	S. 66° E.	2.1	S. 39° E.	0.1	S. 20°W.	3.3	S. 19°W.	3.4	N. 88°W.	1.4	S. 78°W.	1.6
250	S. 19° E.	2.4	S. 1° E.	3.1	.....	.....	.....	.....	S. 34°W.	0.5	S. 59°W.	1.6	.....	.....	.....	.....	S. 19°W.	4.1	S. 22°W.	4.2	W.	1.4	S. 79°W.	1.7
500	S. 2° E.	3.5	S. 10°W.	4.2	S. 4°W.	3.8	S. 4°W.	3.1	S. 84°W.	1.1	S. 69°W.	2.2	S. 59° E.	2.4	S. 23° E.	0.4	S. 25°W.	5.6	S. 31°W.	6.0	S. 71°W.	2.9	S. 73°W.	3.0
750	S. 13°W.	3.7	S. 20°W.	4.6	S. 16°W.	5.4	S. 18°W.	4.3	S. 87°W.	1.8	S. 81°W.	2.7	S. 38° E.	3.3	S. 5°W.	1.3	S. 24°W.	5.4	S. 33°W.	6.0	S. 78°W.	3.4	S. 72°W.	4.0
1,000	S. 19°W.	3.3	S. 27°W.	4.3	S. 19°W.	5.8	S. 25°W.	4.6	N. 86°W.	1.6	S. 84°W.	2.8	S. 21° E.	3.1	S. 32°W.	1.7	S. 28°W.	4.5	S. 35°W.	5.6	S. 71°W.	3.5	S. 77°W.	4.4
1,250	S. 27°W.	3.1	S. 32°W.	4.2	S. 22°W.	5.4	S. 35°W.	4.6	S. 46°W.	1.2	S. 75°W.	2.6	S. 17° E.	2.7	S. 50°W.	2.0	S. 29°W.	3.8	S. 36°W.	5.2	S. 80°W.	4.4	S. 81°W.	5.2
1,500	S. 19°W.	2.6	S. 34°W.	4.2	S. 34°W.	4.7	S. 42°W.	4.6	S. 64°W.	3.3	S. 80°W.	3.8	S.	2.9	S. 61°W.	2.7	S. 29°W.	2.5	S. 34°W.	4.7	S. 77°W.	4.9	S. 84°W.	5.5
2,000	S. 17°W.	2.5	S. 32°W.	3.7	S. 41°W.	4.1	S. 56°W.	4.8	S. 69°W.	3.1	S. 81°W.	4.2	S. 32°W.	2.7	S. 80°W.	4.2	S. 53°W.	2.0	S. 36°W.	4.1	S. 79°W.	3.7	S. 86°W.	6.7
2,500	S. 73°W.	2.1	S. 42°W.	3.8	S. 44°W.	3.1	S. 70°W.	5.4	S. 83°W.	3.8	S. 84°W.	5.0	S. 57°W.	3.3	N. 89°W.	5.9	S. 30°W.	2.0	S. 33°W.	3.6	S. 86°W.	3.9	S. 88°W.	9.1
3,000	N. 79°W.	3.3	S. 54°W.	4.7	S. 43°W.	3.3	S. 70°W.	6.3	S. 87°W.	6.4	S. 83°W.	7.4	S. 71°W.	4.6	W.	7.6	.....	.....	.....	.....	S. 88°W.	5.7	S. 84°W.	11.6
3,500	S. 80°W.	4.9	S. 62°W.	4.9	S. 41°W.	4.9	S. 71°W.	7.3	N. 69°W.	6.4	W.	7.1	N. 57°W.	5.1	N. 77°W.	9.7	.....	.....	.....	.....	N. 72°W.	5.6	S. 82°W.	11.3
4,000	N. 79°W.	8.2	S. 56°W.	6.6	S. 74°W.	3.5	S. 73°W.	7.0	N. 45°W.	10.8	N. 77°W.	7.4	N. 54°W.	12.0	N. 71°W.	10.9	.....	.....	.....	.....	.....	.....	.....	.....
4,500	.....	.....	.....	.....	S. 23° E.	6.7	S. 60°W.	7.7	.....	.....	.....	.....	N. 52°W.	17.4	N. 65°W.	13.1	.....	.....	.....	.....	.....	.....	.....	.....
5,000	.....	.....	.....	.....	S.	6.5	S. 58°W.	8.6	.....	.....	.....	.....	N. 68°W.	19.6	N. 73°W.	16.0	.....	.....	.....	.....	.....	.....	.....	.....

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

By midsummer the atmospheric circulation has usually been reduced to the minimum of activity for the year, and cyclones and anticyclones are of the weakest type, though still of sufficient energy to cause material changes in wind movement with corresponding variations in temperature and other important weather conditions.

July, 1923, was mainly without important changes from normal pressure conditions, and while high and low areas were not of material importance they were sufficiently frequent to afford agreeable changes in temperature, as well as to regulate in a generally satisfactory manner the distribution of rainy and fair weather.

Low-pressure areas were frequent during the first half of the month, particularly in the western mountain districts and over many of the Central and Eastern States, but they were usually of slight intensity and only occasionally did they pursue well-defined paths over material distances. They were favorable to the development of local thunderstorms and these were of frequent occurrence from the Rocky Mountains eastward, save over the southern plains and adjacent regions, and locally in the middle Mississippi Valley and portions of the Northeastern States.

From about the 15th to 23d there was comparative freedom from conditions favoring thunderstorm activity over the central valleys and northern districts, and this was mainly the driest portion of the month over those regions.

From the 27th to 29th a low-pressure area, moving from the central Mississippi Valley eastward to the Atlantic coast, was attended by much needed and copious showers, greatly relieving droughty conditions which had become serious in some of the Middle Atlantic States.

For the month as a whole the average pressures were mainly near the normal, save from the Great Lakes eastward and over the Canadian Maritime Provinces, where they were materially above.

The pressure averages as compared with the preceding month were higher in all parts of both the United States and Canada. This is somewhat unusual, particularly over the eastern districts of Canada and the northeast portions of the United States, where the pressure in July is, as a rule, less than in June, whereas in July, 1923, the averages were far above those for June. Similar conditions prevailed on the Pacific coast, but to a less extent.

Due to the absence of important variations in pressure, winds of injurious velocities were associated almost entirely with thunderstorms. These were numerous, as stated elsewhere, but they were only occasionally accompanied by damaging windstorms, the main features of which appear in the table at the end of this section.

The prevailing winds for the month were principally from southerly points over the Great Plains and from the lower Mississippi Valley eastward; elsewhere they were highly variable.

TEMPERATURE.

Change in temperature from day to day were small, amounting rarely to more than 10° in 24 hours, although there were well recognized warm and cool periods during the month, but these were mainly brought about by continued small daily changes in one direction.

The first few days of the month were cool over the districts to eastward of the Rocky Mountains, particularly in portions of the Gulf States where the minimum temperatures on the morning of the 1st were in some cases nearly as low as ever observed in July. In the far West this period was generally warmer than normal. By the 4th temperatures had returned to near the normal in nearly all districts.

The week ending the 10th had mainly moderate temperatures, the averages being from 2 to 6° above normal over most parts of the central valleys and generally slightly below over the remaining districts.

The week following the 10th was warm over all interior portions of the country, the weekly averages exceeding the normal from 3 to 6° over the Great Plains and far Northwest. In the far Southwest, however, the week was cooler than normal and similar conditions existed, though to a less degree, from the upper Lakes to northern New England and over portions of Georgia and Florida.

The week ending July 24 was warm over the northern two-thirds of the country, the averages for the period ranging up to 9° above normal, with the greatest excesses over the northern districts between the Great Lakes and the Rocky Mountains. At the same time cool weather dominated the southern districts, particularly on the morning of the 20th, when in portions of the Middle Gulf States the temperatures established new low records for July.

The last week of the month had generally high temperatures over the western half and moderately low temperatures for a midsummer month over the eastern half of the country. In the Southern Plains the week was decidedly warm, particularly during the first half, while in New England that portion of the week was distinctly cool.

The more important heated periods were at the beginning of the month in the far Southwest; near the beginning of the second decade from the Lake region southward to the Gulf States; about the 20th to 24th over the Eastern States, Great Plains, and middle Mississippi Valley; and over much of the southern plains and the far West near the end. Maximum temperatures of 100° were reported from nearly all States, reaching extremes of 111° in Kansas and Oklahoma, 114° in Texas, 116° in Arizona and Nevada, and 123° in the depressed valleys of California.

The principal cool periods were on the 1st from the Rocky Mountains eastward, continuing over the 2d in a few sections, on the 20th at points in the Middle Gulf States, and on scattered dates for other portions of the country. Freezing temperatures were reported from exposed points from Pennsylvania to New England and at high elevations in most of the Western Mountain States.

The month as a whole was warmer than normal from Texas northeastward to the lower Lakes and thence westward to the Pacific coast, except for portions of Arizona and southern California, where it was slightly cooler. The month was among the warmest of record for July over portions of the upper Missouri Valley and adjacent areas, and also along the coast of northern California. Over the more eastern portions of the country the month was cooler than normal, particularly over the northern portions of New York and New England, where locally it was the coolest July of record, and it was an unusually cool month in portions of the Middle Gulf States.

PRECIPITATION.

Over the greater part of the country where liberal precipitation usually occurs during the midsummer month, the falls were, on the whole, deficient as compared with the normal. This was particularly the case from Texas and near-by localities northeastward over Oklahoma, Kansas, Missouri, Iowa, and to Lake Michigan, and from the lower Lakes to northern New England. In the Gulf States and thence northeastward to southern New England there was much diversity in the monthly amounts, some localities having generous showers at favorable intervals, while near-by areas suffered from serious shortages. Over the middle and northern Rocky Mountain regions and thence westward, where precipitation is generally insufficient for best crop growth, the falls were frequent and nearly everywhere above normal. This was particularly the case from Colorado northward into the western Canadian Provinces, where precipitation was unusually heavy for the period of the year and in some localities, notably in Wyoming, the month was the wettest of record for July.

In portions of Kansas and generally over Oklahoma and the greater part of Texas, including portions of adjacent States, the precipitation for the month was far less than the normal requirements, and serious need of rain existed at the close, the droughty conditions being augmented by a general lack of sufficient moisture during the latter part of June over the same area and by the high temperature during much of July.

The more or less serious need of rain, being felt in June over many Atlantic coast districts was mainly overcome at various periods during the month, so that by the end no important areas over the eastern portions of the country were seriously in need of rain, save locally in the Middle Atlantic States, principally in northern New York, eastern Pennsylvania, and portions of New Jersey.

In the far Southwest, where the July precipitation is usually the maximum for the year, the falls were timely and mainly more than normally received.

SNOWFALL.

In California snow covered some of the highest peaks of the Sierra Nevada on several dates, an unusual phenomena during the midsummer. In other mountain districts not more than traces of snow were reported.

The supply of water for irrigation, hydroelectric power, etc., appears to have been adequate in the western districts where storage is necessary.

RELATIVE HUMIDITY.

The extremely dry and hot weather prevailing during much of the month over Oklahoma and to the southward moderately influenced the percentage of relative humidity, which ranged up to an extreme of 14 per cent below the normal. The more or less droughty conditions in the middle Mississippi Valley and thence to the Great Lakes and portions of the Northeastern States were associated mainly with deficient relative humidity. In the districts from the middle and northern Great Plains westward to the Pacific the relative humidity was nearly everywhere above normal, due to the general frequency of cloudy, rainy weather. Elsewhere humidity conditions were mainly near the normal.

SEVERE LOCAL STORMS, JULY, 1923.

[The table herewith contains such data as have been received concerning severe local storms that occured during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storms.	Remarks.	Authority.
Westchester Co., N. Y.	4					Hail	Large amount of damage to crops	Official, U. S. Weather Bureau.
Pittsburgh, Pa.	6	P. m.		1		Electrical and wind.	Buildings and wires damaged	Do.
Northeast and east central Iowa.	7					Wind and hail	Growing crops severely damaged	Do.
North Dakota (southeast portion of).	8					Wind, rain, and hail	Heavy damage reported	Do.
Pittsburgh, Pa., and vicinity.	10					Electrical and wind.	Electric light and power lines blown down and sign boards damaged.	Chicago (Ill.) Daily News.
Ringling, Mont. (vicinity of).	10					Tornado	House and barn wrecked	Official, U. S. Weather Bureau.
Western Iowa	10				$200,000	Wind and hail	Heavy crop loss	Do.
Detroit, Mich.	10					Electrical, wind, and hail.	Considerable damage by lightning and floods	Do.
Sanders Range, Md.	11			3		Electrical	Tent destroyed and 14 persons injured	Do.
Clinton Co., Ind. (western part of).	11					Wind, rain, and hail.	Growing crops badly damaged	Do.
Decatur, Ill. (vicinity of)	11			1		Thunderstorm	Considerable minor damage; two barns destroyed by lightning.	Do.
Oak Hill, Ill. (vicinity of)	11				10,000	do	General damage reported	Do.
Granite, Okla.	12			2		Tornado	Considerable property loss	Dallas (Tex.) Morning News.
Dayville, Oreg. (vicinity of)	13					Heavy rains	Much damage to crops; some loss of live stock	Official, U. S. Weather Bureau.
Wichita, Kans. (vicinity of)	14	P. m.		1		Wind, rain, and hail.	Farm houses damaged, barns blown down, crops destroyed, and other minor damage.	Wichita (Kans.) Beacon.
Green Bay, Wis., and vicinity.	14	do				Wind and rain	Several persons injured; houses and orchards damaged.	Official, U. S. Weather Bureau. Green Bay (Wis.) Press Gazette.
Dayville, Oreg. (vicinity of)	15					Heavy rains	Crops considerably damaged; some live stock killed.	Official, U. S. Weather Bureau.
Gallatin Valley, Mont. (near Willow Creek).	16	P. m.				Wind, rain, and hail.	Extensive damage to homes, crops, and communication lines.	Post (Denver, Colo.).
Liberty, Ariz. (near)	22	do			2,000–3,000	Thunderstorm	Highways damaged and small buildings and poles blown down; minor railway washouts.	Official, U. S. Weather Bureau.
Essex Co., N. J.	22	do		2		Electrical and wind.	Poles blown down and traffic interfered with; many persons injured.	Herald (New York).
Tullahoma, Tenn.	22					Wind and rain	General damage reported	Official, U. S. Weather Bureau.
Knoxville, Tenn.	22				25,000	Thunderstorm	Trees and poles blown down; plate glass windows broken.	Do.
Las Vegas, N. Mex.	23					Wind and floods	Considerable damage	Do.
Glendale, Ariz., and vicinity.	29	P. m.			5,000	Wind and rain	Several buildings destroyed and others damaged; other minor damage.	Do.
Parts of Jasper, Newton, McDonald, and Barry Counties, Mo.	29	do			300,000	Wind, rain, and hail.	Heavy damage, principally to crops	Do.

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

So far as the occurrence of conditions calling for the issuance of special warnings is concerned, July, 1923, in the Washington Forecast District was uneventful. The only warnings of any character disseminated were those for small craft on the mornings of the 19th and 25th. On the first-named date a disturbance of minor energy was off Cape Hatteras apparently moving northeastward, and small-craft warnings were advised at and between Hatteras and Delaware Breakwater. Later, at 1 p. m., an advisory message concerning this disturbance was sent to stations on the middle Atlantic coast. As the disturbance moved northeastward it apparently lost energy.

On the morning of the 25th small-craft warnings were sent to stations on the New England coast in connection with a disturbance of moderate character that was then passing eastward over the New England states. No increase in energy took place as the disturbance moved out to sea.

In the West Indies and over the Caribbean Sea the month passed without any evidences of the presence of storms of tropical origin.—*C. A. Donnel.*

CHICAGO FORECAST DISTRICT.

No warnings of any kind were issued for any portion of the Chicago Forecast District during July, 1923. Special forecasts were issued on July 3 and 4 in connection with the National Elimination Balloon Race held at Indianapolis, Ind., on the 4th.—*Chas. L. Mitchell.*

DENVER FORECAST DISTRICT.

Areas of low pressure, mostly in the form of troughs, prevailed on the Rocky Mountain Plateau during the greater part of the month, attended by frequent thunderstorms, especially in Colorado and New Mexico. Numerous excessive local downpours occurred east of the divide in both of these States. A LOW of marked intensity that was over British Columbia on the 29th moved southeastward across the Missouri Valley on the 31st, attended by high temperatures in the northern portion of the district. This disturbance was followed immediately by an area of high pressure and lower temperature on the northeastern slope, thunderstorms and cooler weather extending to northern New Mexico.

No special warnings were issued during the month.—*J. M. Sherier.*

NEW ORLEANS FORECAST DISTRICT.

Small-craft warnings were ordered displayed on the Texas coast, July 1, and the display was justified by the subsequent conditions. No other storm warnings were displayed and no storm occurred without warnings.

Special forecasts to alfalfa growers were sent to interests in Oklahoma whenever rains were forecast.—*I. M. Cline.*

SAN FRANCISCO FORECAST DISTRICT.

Light rain fell in Washington and Oregon on the 6th and 7th, caused by a depression which formed over the lower Colorado River Valley on the 5th and moved rapidly northeastward over the plateau. The peculiar feature of this depression was that it caused neither showers nor thunderstorms in the plateau. Scattered thunderstorms occurred in Nevada, Idaho, and the eastern portions of Washington and Oregon during the middle and latter part of the month, caused by depressions forming over the plateau.

There appears to be a close connection between the east and west oscillation of the North Pacific HIGH and the formation of depressions over the plateau and lower Colorado River Valley. During July, the HIGH would move slowly westward, impinging lightly on the coast; and then, without moving inland and often without the usual breaking off of a secondary, it would swing back into the Pacific and a depression would begin to develop over the plateau or lower valley of the Colorado. This condition occurred several times during June and July.

Fire-weather warnings were issued in California on the 3d and in Washington, Oregon, and Idaho on the 13th, and were fairly successful.

No storm warnings were issued.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

The precipitation over the eastern portion of the country was nearly normal during July, and as a result no rises of consequence were noted in the rivers of the Atlantic drainage, except in the Santee River system, where excessive rains on July 1 and 2 caused moderate rises. Warnings of flood stages in the Broad, Saluda, and Congaree Rivers were issued on July 2, but were not verified on account of unusually heavy pooling of water at dams in both the Broad and Saluda Rivers.

Owing to heavy rains on July 17–18 over southwestern Mississippi, the West Pearl River at Pearl River, La., reached a stage of 14.2 feet, 1.2 feet above flood stage. No warnings were issued, as it was thought that the swamps of the lower Pearl River would absorb most of the water before it reached Pearl River. Damage to the amount of $10,000 was caused by this flood, $5,000 to highways and bridges, and $5,000 by suspension of business.

The Yazoo River flood ended on July 4, when the river at Yazoo City, Miss., fell below the flood stage of 25 feet. The river at this place had been continuously above the flood stage since March 2.

Heavy to excessive rains fell over the lower Missouri and the western half of the Grand River drainage basins on July 3–4. On the Missouri River the flood stage was slightly exceeded at Waverly, Mo., and on the Grand River at Chillicothe and Brunswick, Mo.

Warnings were issued for these floods and the resulting damage was very slight.

Moderate rains over the upper Neosho drainage basin during the first decade of the month caused a considerable rise in that river. A stage of 23.3 feet, or 1.3 feet above flood stage, was reached at Neosho Rapids, Kans. Flood warnings were not issued and practically no damage resulted, as the flood occurred very soon after the great floods of June, 1923.

The flood stage of 10 feet was exceeded in the Arkansas River at Pueblo, Colo., by 1.4 feet on July 12, due to heavy rains in the upper Arkansas drainage basin. Warnings were issued at the proper time and no serious damage was reported. Other local warnings for moderate rises in the upper drainage area were issued on July 18 and 25.

The Colorado River remained above flood stage at Parker, Ariz., throughout the month and at Lees Ferry, Ariz., until the 17th.

ANNUAL RISE OF COLUMBIA RIVER.

[From report of Mr. R. C. Mize, meteorologist, Portland, Oreg.]

At the close of March the following forecast was made: "With normal temperature prevailing during the remainder of the spring, the maximum stage of water at Portland during the annual rise of the Columbia should be about 20 feet."

Temperature averaged slightly above normal during April and May, permitting ample run-off during those months and causing a very moderate flood, with a crest stage at Portland of 19.8 feet on June 16, or 0.5 foot below the 46-year average, and only 0.2 foot below the stage forecast in March.

Reports from 197 interested parties showed losses of $46,739 and saving of property by warnings of $76,020. The largest single item of loss was due to suspension of business. Losses of prospective crops amounted to $8,088. All dikes held.

There was the usual number of destructive overflows of small streams, due to local torrential rains, and a great amount of damage was done to roads, bridges, crops, etc. The most severe of these floods occurred on July 15 and 16 in eastern Colorado and in central, eastern, and northeastern Wyoming from July 22 to 27, inclusive. Losses in Colorado were unreported, but those in Wyoming, according to estimates obtained by Mr. George W. Pitman, meteorologist in charge of the Weather Bureau office at Cheyenne, Wyo., were about $775,000, of which $300,000 was in land and growing crops and as much to railroads. Other severe local floods occurred on July 8 in Bristol, Tenn., and Bristol, Va., and adjacent sections, and on July 30 in the Patapsco Valley of Maryland, Pennsylvania generally, and southeastern Virginia. The damage done amounted to perhaps $1,000,000, of which more than one-half was in Maryland and about one-fourth in Virginia.

The Patapsco River flood was the greatest since the flood of July 24, 1868, when the river at Ellicott City, Md., rose 5 feet in 10 minutes. Thirty-five persons were drowned, and the losses amounted to about $1,000,000.

WATER LEVEL OF GREAT SALT LAKE, UTAH.

After having reached its highest level since 1889, the waters of Great Salt Lake began to fall during July. During the month of June the peak stage of 8 feet above the zero of the gage prevailed, but by July 15 the water had risen to 7.6 feet, with a further slow decline indicated.

Flood stages during July, 1923.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
EAST GULF DRAINAGE.		*Feet.*			*Feet.*	
West Pearl	Pearl River, La	13	25	28	14.2	26
MISSISSIPPI DRAINAGE.						
Arkansas	Pueblo, Colo	10	12	12	11.4	12
Neosho	Neosho Rapids, Kans.	22	6	6	23.3	6
Yazoo	Yazoo City, Miss.	25	(1)	4	25.8	1
Missouri	Waverly, Mo.	23	7	8	23.3	7
Grand	Chillicothe, Mo.	18	6	6	18.4	6
Do	Brunswick, Mo.	10	(1)	10	12.7	7
COLORADO DRAINAGE.						
Colorado	Lees Ferry, Ariz.	12	(1)	17	13.9	1
Do	Parker, Ariz.	7	(1)	(2)	9.2	16
COLUMBIA BASIN DRAINAGE.						
Columbia	Marcus, Wash.	24	(1)	17	28.1	1
Do	Vancouver, Wash.	15	(1)	12	18.8	1
Willamette	Portland, Oreg.	15	(1)	11	18.0	1

[1] Continued from June. [2] Continued into August.

MEAN LAKE LEVELS DURING JULY, 1923.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Aug. 4, 1923.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during July, 1923:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.87	579.89	572.04	245.80
Above or below—				
Mean stage of June, 1923	+0.20	+0.03	+0.02	−0.13
Mean stage of July, 1922	−0.57	−0.79	−0.70	−1.12
Average stage for July, last 10 years	−0.77	−1.16	−0.93	−1.07
Highest recorded July stage	−1.95	−3.69	−2.37	−2.92
Lowest recorded July stage	+0.39	−0.01	+0.58	+1.21
Average relation of the July level to—				
June level	.....	+0.10	0.00	0.00
August level	.....	+0.10	+0.20	+0.30

[1] Lake St. Clair level: In July, 574.87 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JULY, 1923.

By J. B. KINCER, Meteorologist.

Exceptionally favorable weather prevailed for harvesting winter wheat during the first 10 days of July throughout the interior of the country, except for some interruption by rain in the upper Ohio Valley States. Warm weather in the spring wheat region, however, was rather unfavorable for that crop, but was favorable for corn in most of the principal producing areas. Beneficial rains fell during this period in the middle Atlantic coast area, and there was less rainfall in much of the Southeast, which was of benefit to staple crops.

Cotton made fair to very good progress in the central and eastern portions of the belt, though it was becoming too dry in some western cotton-growing districts. Exceptionally favorable weather continued in the more northwestern States where further substantial rains were received.

The second decade of the month had mostly favorable weather for agricultural interests in much the greater part of the country. Copious rains about the middle of the month largely relieved droughty conditions in the Northeastern States, while increased moisture benefited vegetation in the middle Atlantic area, though many localities continued too dry, particularly in Pennsylvania.

Threshing progressed in the southern portion of the Winter Wheat Belt with no material interruption, except in parts of Kansas where there was some delay by rain and some damage to wheat in shock. During this period excellent weather for the rapid growth of corn was the rule, except where it was too dry in the southern Great Plains. It was too warm, however, for the best development of spring wheat, but cotton showed general improvement in much of the belt, though that planted late needed rain rather badly in some western localities. The best showers of the season, so far, occurred in the grazing area of the far Southwest where long drought had prevailed, although the range continued too dry in some sections.

By the latter part of the month the drought had been intensified by continued absence of rain from central Kansas southward, and most crops showed deterioration, especially corn. Rain was badly needed also in parts of Iowa, Illinois, Kentucky, and Arkansas, but much-needed

moisture was received in the more eastern States from northern Virginia northward. Warm weather continued in the spring-wheat region until the last week in the month, and rust developed rapidly, the late crop being seriously injured in many portions of the belt. Cotton made, as a rule, unfavorable progress during the latter part of the month, it being too dry in the western portion of the belt and too cloudy and wet in most of the central and eastern portions, though more favorable in the northeast. Exceptionally favorable weather continued for ranges and stock in the northwestern grazing districts, especially in Montana.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1923.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	78.5	−1.4	Madison	101	12	Maple Grove	48	1	5.23	−0.59	Marion	11.04	Evergreen	1.28
Arizona	79.9	−0.2	2 stations	116	[2]1	Henry's Camp	38	7	2.92	+0.28	San Rafael Ranch	8.41	Supai	T.
Arkansas	79.9	0.0	Hope	105	24	Rogers	48	1	3.53	−0.39	Little Rock	7.86	Harrison	0.33
California	71.4	−1.8	Greenland Ranch	123	29	Portola	29	18	0.05	−0.03	Campo	1.35	148 stations	0.00
Colorado	67.5	+1.0	Lamar	106	31	Longs Peak	24	20	3.18	+0.86	Silver Lake	11.50	Garnett	0.34
Florida	80.4	−0.7	New Smyrna	100	17	Cottage Hill	60	20	6.97	−0.19	Ocala	12.80	Sand Key	1.10
Georgia	78.8	−1.3	Dublin	105	13	Blue Ridge	48	7	4.40	−1.37	Thomasville	10.59	Newnan	0.52
Hawaii	74.1	+0.1	Waianae	92	22	5 stations	53	[2]1	5.40	−1.02	Puu Kukui (upper)	32.00	6 stations	0.00
Idaho	69.7	+2.0	Weiser	110	[2]23	Stanley	26	4	0.93	+0.19	Bogus Creek	2.53	American Falls	0.02
Illinois	77.1	+1.2	Carbondale	107	24	Mount Carroll	47	1	2.15	−1.29	Freeport	7.05	Henry	0.05
Indiana	75.2	−0.1	Veedersburg	100	21	2 stations	41	1	3.51	−0.28	Frankfort	9.46	Terre Haute	0.59
Iowa	76.5	+2.4	Nora Springs	102	22	Little Sioux	47	28	1.75	−2.21	Mount Ayr	5.54	2 stations	0.29
Kansas	78.7	+0.3	Fredonia	111	24	Hoxie	49	29	3.15	−0.31	McFarland	10.12	Beaver	0.14
Kentucky	76.8	+0.1	3 stations	99	[2]12	Eubank	44	1	3.59	−0.71	Anchorage	7.79	Marion	0.21
Louisiana	80.2	−1.4	Plain Dealing	106	25	Farmerville	67	1	6.98	+0.56	Schriever	15.15	Robeline	1.68
Maryland-Delaware	73.9	−1.3	Boyds, Md	101	[2]20	Freeland, Md	39	1	4.61	+0.27	Millsboro, Del	8.87	Chesapeake City, Md	1.68
Michigan	68.6	+0.1	3 stations	98	[2]10	Humboldt	35	4	3.20	+0.25	Ironwood	10.71	Ludington	0.51
Minnesota	72.9	+3.6	International Falls	103	22	Itasca State Park	36	1	2.82	−0.77	Two Harbors	7.56	Winnebago	0.71
Mississippi	79.4	−1.4	Yazoo City	102	25	2 stations	54	1	5.80	+0.55	Pearlington	12.08	University	2.25
Missouri	78.2	+0.7	2 stations	105	24	Clinton	50	[2]1	3.07	−0.89	Waverly	10.29	Tarkio	0.24
Montana	69.2	+3.5	Knowlton	107	19	Wisdom	25	28	2.34	+0.75	Wheaton	7.42	Pleasant Valley	0.00
Nebraska	76.5	+1.9	Holdrege	104	10	2 stations	45	[2]1	2.83	−0.59	Bingham	8.61	Stanton	0.36
Nevada	73.9	+1.1	Pahrump	116	28	Rye Patch	24	7	0.42	+0.09	Searchlight	2.52	7 stations	0.00
New England	65.9	−2.6	Norwalk, Conn	99	[2]20	Chelsea, Vt	31	1	3.14	−0.58	Bennington, Vt	5.68	New Haven, Conn	1.49
New Jersey	71.9	−1.9	Burlington	102	21	Charlotteburg	40	1	3.88	−0.68	Newark	6.28	Woodcliffe Lake	0.93
New Mexico	72.7	+0.8	Orogrande	110	1	Elizabethtown	34	3	2.00	−0.70	Cloudcroft	5.90	Cundiyo	0.05
New York	67.8	−1.8	Scarsdale	101	21	Indian Lake	32	7	2.84	−1.08	Andover	5.33	Lowville	0.58
North Carolina	75.6	−0.5	Sloan	104	21	Mount Mitchell	42	18	5.93	−0.63	Swansboro	14.40	Tryon	1.15
North Dakota	71.2	+3.7	Pembina	103	9	Turtle Lake	35	30	3.14	+0.53	Washburn	6.16	Langdon	0.70
Ohio	72.7	−0.6	Lancaster	100	11	Canfield	41	23	3.57	−0.28	Toboso	11.34	Hamilton	1.21
Oklahoma	83.2	+2.3	Okeene	111	31	Goodwell	55	2	1.10	−1.82	Hurley	5.83	4 stations	T.
Oregon	67.3	+0.9	2 stations	106	13	La Pine	27	31	1.18	+0.59	Welches	3.94	2 stations	0.04
Pennsylvania	71.0	−1.0	Gettysburg	100	[2]20	West Bingham	32	23	4.24	−0.09	Vandegrift	9.86	Ansonia	0.92
Porto Rico	78.5	−0.3	Lares	97	11	4 stations	58	[2]3	4.49	−2.16	Maricao	18.50	Santa Rita	1.25
South Carolina	79.0	−0.8	Society Hill	104	5	3 stations	57	[2]1	4.50	−1.44	Georgetown	8.88	Calhoun Falls	1.15
South Dakota	74.6	+3.6	Dupree	105	18	Lead	40	29	3.45	+0.15	Deadwood	9.30	Ardmore	0.61
Tennessee	77.2	−0.3	2 stations	101	[2]8	Pinewood	43	1	3.99	−0.68	Charleston	7.82	Pinewood	0.98
Texas	83.5	+0.6	Henrietta	114	[2]15	Seminole	50	12	1.67	−1.06	Bon Weir	8.90	6 stations	0.00
Utah	72.7	+1.6	2 stations	110	[2]29	3 stations	37	[2]1	1.19	+0.23	Mammoth Ranger Station	3.80	3 stations	T.
Virginia	74.3	−1.1	Lincoln	100	[2]20	Burkes Garden	44	[2]3	5.12	+0.11	Mayhurst	11.14	Dale Enterprise	2.49
Washington	67.6	+1.4	Trinidad	109	[2]22	Paradise Inn	32	[2]3	1.17	+0.46	Kettle Falls	2.63	Wahluke	0.00
West Virginia	71.7	−1.2	Inwood	100	20	Cheat Bridge	37	1	4.70	+0.12	Elizabeth	9.46	Powellton	2.22
Wisconsin	71.3	+2.0	2 stations	100	[2]9	Hayward	36	1	3.24	−0.53	High Falls	7.89	La Crosse	0.62
Wyoming	68.3	+2.7	Basin	103	20	Snake River	27	4	2.46	+1.06	Sheridan	6.37	Eden	0.00

[1] For description of tables and charts, see REVIEW.
[2] Other dates also.

TABLE I.—*Climatological data for weather bureau stations, July, 1923.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
New England.							**66.6**	**−2.2**											**77**	**3.01**	**− 0.6**										**5.8**		
Eastport	76	67	85	29.89	29.97	+.04	58.8	−1.6	84	21	68	46	2	50	31		54	51	81	2.69	−0.7	13	5,556	s.	24	ne.	7	8	7	16	6.6	0.0	0.0
Greenville, Me	1,070	6	....	28.86	30.00	.....	62.0	.....	86	19	72	40	27	52	34		.....	.....	....	4.34	.....	13	.....	.....	.....	.....	.....	12	5	14	....	0.0	0.0
Portland, Me	103	82	117	29.89	30.01	+.06	66.2	−1.9	89	20	74	53	27	58	28		59	55	70	2.92	−0.3	9	5,507	s.	25	nw.	6	13	7	11	5.3	0.0	0.0
Concord	288	70	79	29.69	30.06	+.04	66.3	−2.2	92	20	78	45	24	54	37		.....	.....	....	4.35	+0.6	7	2,751	n.	18	nw.	26	20	5	6	3.9	0.0	0.0
Burlington	404	11	48	29.57	29.99	+.05	65.7	−2.5	88	20	76	46	23	55	35		.....	.....	....	2.26	−1.5	12	5,152	n.	26	nw.	21	11	9	11	5.4	0.0	0.0
Northfield	876	12	60	29.08	30.02	+.08	62.2	−4.4	87	20	75	40	24	49	42		59	57	83	2.43	−1.3	13	4,005	s.	23	n.	7	7	11	13	6.2	0.0	0.0
Boston	125	115	188	29.86	30.00	+.04	70.0	−1.7	94	20	78	56	24	62	28		62	58	69	3.36	0.0	8	5,639	sw.	25	w.	21	7	11	13	6.6	0.0	0.0
Nantucket	12	14	90	29.99	30.00	+.02	66.5	−1.0	89	21	73	55	31	60	25		62	60	84	3.48	+0.8	7	8,951	sw.	34	ne.	22	8	11	12	6.2	0.0	0.0
Block Island	26	11	46	29.97	30.00	+.03	66.6	−1.8	90	21	73	54	24	60	22		63	61	88	2.02	−1.3	9	8,188	sw.	58	n.	21	15	4	12	4.9	0.0	0.0
Providence	160	215	251	29.83	30.00	+.03	69.0	−4.4	93	20	78	52	24	60	27		62	58	72	3.09	−0.4	10	6,676	w.	40	nw.	16	5	11	15	6.6	0.0	0.0
Hartford	159	122	140	29.83	30.00	+.03	70.4	−1.2	94	20	80	51	24	61	31		63	59	72	4.99	+0.9	10	4,442	s.	28	sw.	24	8	6	17	6.5	0.0	0.0
New Haven	106	74	153	29.89	30.00	+.03	70.6	−1.2	95	21	79	54	24	62	33		64	60	73	1.49	−3.3	9	5,517	s.	28	sw.	9	9	12	10	5.7	0.0	0.0
Middle Atlantic States.							**73.6**	**−1.1**											**72**	**4.15**	**−0.2**										**5.4**		
Albany	97	102	115	29.90	30.00	+.04	70.6	−2.0	94	20	81	52	1	60	32		62	57	66	3.89	0.0	11	4,669	s.	38	s.	24	17	11	3	3.2	0.0	0.0
Binghamton	871	10	84	29.08	30.00	+.03	69.2	−0.7	92	20	81	47	.1	57	37		.....	.....	....	2.26	−1.3	13	3,287	n.	22	sw.	24	8	12	11	5.7	0.0	0.0
New York	314	414	454	29.68	30.00	+.02	72.3	−1.5	94	20	80	57	3	65	29		64	61	72	4.68	+0.1	12	8,577	s.	39	w.	10	6	14	11	6.1	0.0	0.0
Harrisburg	374	94	104	29.62	30.01	+.03	74.2	−0.3	94	21	84	54	1	65	30		64	59	64	3.33	−0.5	9	3,948	nw.	24	ne.	16	7	13	11	6.0	0.0	0.0
Philadelphia	114	123	190	29.89	30.01	+.03	75.2	−1.0	99	21	83	62	3	67	26		65	60	66	3.51	−0.8	12	6,446	s.	25	sw.	24	9	11	11	5.8	0.0	0.0
Reading	325	81	98	29.66	30.00	.....	74.4	.....	94	21	83	54	1	65	28		66	61	68	2.89	−1.3	14	3,621	se.	19	se.	30	5	18	8	5.6	0.0	0.0
Scranton	805	111	119	29.16	30.01	+.03	70.8	−1.0	94	20	82	48	1	60	37		63	58	67	4.72	+0.9	12	3,972	n.	23	nw.	25	10	10	11	5.8	0.0	0.0
Atlantic City	52	37	172	29.94	29.99	+.01	72.2	+0.1	98	21	78	61	9	67	32		67	65	80	5.36	+1.6	13	10,487	s.	35	ne.	23	9	13	9	5.0	0.0	0.0
Cape May	18	13	49	30.01	30.03	+.05	73.7	+0.3	98	21	80	59	1	67	29		68	65	80	4.77	+1.0	11	5,440	se.	24	se.	24	11	5	15	6.0	0.0	0.0
Sandy Hook	22	10	57	29.98	30.00	.....	71.9	.....	94	21	78	58	3	66	25		65	62	77	2.29	.....	12	8,401	s.	38	n.	6	8	14	9	5.2	0.0	0.0
Trenton	190	159	183	29.80	30.00	.....	73.0	.....	96	21	83	56	1	64	32		64	60	69	3.18	−1.6	12	6,839	s.	38	nw.	6	9	10	12	5.9	0.0	0.0
Baltimore	123	100	113	29.86	29.99	+.01	76.7	−0.5	99	21	85	59	1	69	26		67	63	67	2.04	−2.8	12	4,188	s.	26	ne.	16	10	11	10	5.5	0.0	0.0
Washington	112	62	85	29.88	29.99	−.01	75.7	−1.1	96	21	85	54	1	66	33		68	64	71	4.92	+0.3	10	3,175	s.	23	nw.	5	10	12	9	5.5	0.0	0.0
Lynchburg	681	153	188	29.28	30.00	−.01	76.5	−1.0	96	11	87	59	19	66	32		67	63	68	2.52	−1.5	10	4,598	w.	27	se.	30	13	11	7	4.7	0.0	0.0
Norfolk	91	170	205	29.91	30.00	.00	77.0	−1.7	97	21	85	62	10	69	27		70	67	78	4.14	−1.7	13	8,399	e.	45	w.	6	6	17	8	5.9	0.0	0.0
Richmond	144	11	52	29.86	30.00	−.01	76.4	−2.8	97	21	87	60	1	66	33		68	65	75	10.87	+6.4	12	4,701	se.	40	ne.	30	12	11	8	5.3	0.0	0.0
Wytheville	2,304	49	55	27.71	30.02	+.01	69.8	−2.8	88	15	80	52	3	60	30		64	62	82	3.27	−1.2	13	2,987	w.	18	w.	6	12	11	8	4.8	0.0	0.0
South Atlantic States.							**78.2**	**−1.1**											**78**	**6.48**	**+0.4**										**5.9**		
Asheville	2,255	70	84	27.74	30.03	+.01	71.4	−0.3	88	12	81	51	1	62	29		65	62	81	4.54	−0.2	18	3,785	nw.	26	n.	12	8	17	6	4.9	0.0	0.0
Charlotte	779	55	62	29.19	30.00	−.02	78.6	+0.2	98	12	88	62	3	69	27		69	66	71	5.89	+0.4	13	2,744	ne.	25	nw.	6	7	13	11	6.1	0.0	0.0
Hatteras	11	11	50	29.99	30.00	−.01	77.0	−1.2	88	21	82	68	10	72	17		73	71	83	11.69	+5.6	16	10,626	sw.	52	w.	6	7	12	12	5.7	0.0	0.0
Manteo	12	5	42	....	....	....	.....	.....	....	....	....	....	....	....	....		....	....	....	.....	.....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Raleigh	376	103	110	29.61	29.99	−.03	77.4	−1.1	95	12	87	62	19	68	26		69	66	74	6.62	+0.5	15	5,284	sw.	46	ne.	6	5	15	11	6.4	0.0	0.0
Wilmington	78	81	91	29.94	30.02	+.01	78.0	−1.1	92	22	85	64	10	71	22		73	71	84	8.77	+1.8	13	5,999	sw.	32	w.	25	9	13	9	5.5	0.0	0.0
Charleston	48	11	92	29.97	30.02	−.01	80.1	−1.3	96	7	86	67	19	74	20		74	72	79	7.23	0.0	18	7,291	sw.	35	sw.	25	5	11	15	6.8	0.0	0.0
Columbia, S. C	351	41	57	29.64	30.01	−.01	79.8	−1.3	97	13	89	64	1	70	26		71	68	77	2.37	−3.7	12	4,601	s.	42	sw.	25	11	10	10	5.4	0.0	0.0
Due West	711	10	55	29.28	30.04	.....	78.4	.....	96	12	88	62	1	68	28		.....	.....	....	3.15	.....	8	5,457	nw.	38	nw.	7	6	16	9	6.0	0.0	0.0
Greenville, S. C	1,039	113	122	28.93	30.00	.....	77.2	.....	95	12	86	62	2	68	24		69	65	72	6.21	.....	11	5,014	ne.	35	w.	13	8	15	8	5.2	0.0	0.0
Augusta	180	62	77	29.81	30.00	−.02	80.0	−1.3	99	13	90	63	1	70	27		72	69	73	7.03	+1.7	11	3,288	s.	25	se.	27	8	10	13	6.1	0.0	0.0
Savannah	65	150	194	29.95	30.02	−.01	80.0	−1.5	98	13	88	67	19	72	24		73	71	82	5.47	−0.7	17	7,438	sw.	44	nw.	8	8	9	14	5.9	0.0	0.0
Jacksonville	43	209	245	29.98	30.03	.00	80.0	−2.1	94	13	87	68	18	72	22		73	71	79	5.14	−1.1	15	7,998	sw.	44	se.	14	4	11	16	6.8	0.0	0.0
Florida Peninsula.							**81.5**	**−0.7**											**77**	**4.32**	**−2.1**										**5.6**		
Key West	22	10	64	30.00	30.02	−.01	82.8	−0.7	90	17	88	69	1	78	19		76	73	74	2.88	−0.7	11	6,021	se.	29	e.	1	9	16	6	4.7	0.0	0.0
Miami	25	71	79	30.02	30.05	.....	80.7	−1.2	90	9	86	72	10	75	18		75	73	77	5.20	−2.0	22	4,923	se.	28	nw.	18	5	15	11	6.2	0.0	0.0
Sand Key	23	39	72	30.01	30.04	+.01	81.0	.....	88	28	84	71	3	78	12		76	74	77	1.10	.....	11	7,095	se.	39	e.	1	11	14	6	4.9	0.0	0.0
Tampa	35	79	87	30.00	30.03	−.01	81.0	−0.2	92	6	87	68	1	74	19		74	72	80	4.88	−3.6	17	3,836	w.	31	ne.	4	1	21	9	6.6	0.0	0.0
East Gulf States.							**78.7**	**−1.9**											**79**	**5.89**	**+0.6**										**6.0**		
Atlanta	1,174	190	216	28.80	30.02	.00	77.1	−1.0	92	24	86	60	1	68	24		70	66	74	2.60	−2.1	8	6,358	nw.	30	se.	2	10	10	11	5.5	0.0	0.0
Macon	370	78	87	29.62	30.01	−.01	79.3	−0.4	97	13	89	59	1	70	27		71	68	74	5.33	+0.7	13	3,742	sw.	31	w.	25	6	11	14	6.2	0.0	0.0
Thomasville	273	49	58	29.73	30.02	−.01	78.4	−3.4	96	14	87	60	19	70	29		72	71	84	10.59	+5.3	18	2,821	sw.	29	sw.	14	2	9	20	7.6	0.0	0.0
Apalachicola	36	42	49	29.98	30.02	.....	79.0	.....	93	13	85	68	3	73	22		74	73	83	8.54	.....	18	5,077	sw.	33	se.	3	6	18	7	5.7	0.0	0.0
Pensacola	56	149	185	29.96	30.02	+.01	78.2	−2.8	93	13	84	62	20	72	20		74	72	83	7.28	0.0	12	7,818	w.	40	nw.	29	2	12	17	7.1	0.0	0.0
Anniston	741	9	57	29.27	30.04	+.02	77.2	−0.7	95	24	88	53	1	66	30		.....	.....	....	3.46	−1.3	10	2,555	sw.	20	n.	8	13	16	2	4.4	0.0	0.0
Birmingham	700	11	48	29.28	30.03	+.02	78.5	−3.0	95	12	88	60	1	69	25		70	68	76	6.42	+1.7	10	3,298	nw.	20	s.	6	10	13	8	4.9	0.0	0.0
Mobile	57	125	161	29.96	30.02	+.01	79.8	−0.9	94	23	88	64	20	72	21		74	72	84	4.98	−2.1	14	5,292	sw.	40	e.	22	4	15	12	6.8	0.0	0.0
Montgomery	223	100	112	29.77	30.02	.00	79.3	−2.4	96	12	88	62	1	71	24		72	69	76	3.81	−0.9	11	3,774	w.	36	ne.	8	9	7	15	6.3	0.0	0.0
Corinth	469	6	....	....	....	....	79.5	.....	96	7	90	58	2	69	30		.....	.....	....	3.76	.....	8	.....	sw.	.....	.....	.....	4	23	4	....	0.0	0.0
Meridian	375	85	93	29.62	30.00	−.02	77.9	−2.1	93	12	87	60	1	69	24		71	69	78	7.77	+3.3	13	3,044	sw.	24	nw.	25	10	14	7	5.1	0.0	0.0
Vicksburg	247	65	73	29.74	30.02	+.02	79.6	−1.7	94	25	88	65	1	71	24		73	71	79	3.85	−0.6	11	3,989	se.	25	nw.	25	11	8	12	5.4	0.0	0.0
New Orleans	53	76	84	29.96	30.01	+.01	80.2	−2.2	95	24	87	66	18	73	20		74	72	82	8.72	+2.2	16	4,288	sw.	26	sw.	9	3	15	13	6.6	0.0	0.0
West Gulf States.							**82.3**	**+0.3**											**72**	**3.04**	**−0.1**										**4.6**		
Shreveport	249	77	93	29.72	29.98	.00	82.4	+0.3	104	25	92	64	1	72	30		73	70	71	3.40	−0.3	6	4,483	s.	29	ne.	30	15	13	3	4.0	0.0	0.0
Bentonville	1,303	11	44	....	....	....	78.4	−0.1	98	24	89	59	1	68	27		.....	.....	....	1.28	.....	3	.....	.....	.....	.....	.....	16	11	4	....	0.0	0.0
Fort Smith	457	79	94	29.48	29.95	−.02	82.4	+1.4	101	24	93	63	1	72	26		72	68	68	3.41	−0.4	9	4,368	e.	42	w.	15	13	14	4	4.6	0.0	0.0
Little Rock	357	136	144	29.60	29.97	−.02	80.0	−0.9	98	24	89	61	1	71	23		72	69	74	7.86	+3.9	8	4,506	s.	41	w.	25	9	13	9	5.4	0.0	0.0
Brownsville	57	53	61	29.89	29.95	.....	83.6	.....	95	24	91	71	1	76	20		75	73	78	1.53	.....	8	6,835	s.	24	n.	1	17	13	1	2.9	0.0	0.0
Corpus Christi	20	11	73	29.95	29.97	+.01	82.9	+0.2	95	29	89	70	8	76	18		76	74	79	1.06	−0.6	5	9,861	s.	33	se.	16	12	14	5	4.5	0.0	0.0
Dallas	512	109	117	29.43	29.96	.....	85.6	.....	103	25	95	69	21	76	23		.....	.....	....	0.62	.....	2	5,107	s.	26	ne.	18	12	16	4	4.5	0.0	0.0
Fort Worth	670	106	114	29.23	29.93	−.03	85.2	+1.5	105	27	96	68	7	74	32		70	64	57	0.99	−2.0	2	5,549	e.	31	w.	27	10	18	3	4.5	0.0	0.0
Galveston	54	106	114	29.95	30.01	+.03	81.8	−1.6	91	23	86	68	1	78	14		76	74	81	5.80	+1.8	10	7,054	s.	31	se.	1	8	15	8	5.1	0.0	0.0
Groesbeck	461	11	56	29.49	29.96	.....	84.5	.....	101	31	96	66	21	73	27		.....	.....	....	0.14	.....	2	7,064	sw.	50	s.	8	10	19	2	4.7	0.0	0.0
Houston	138	111	121	29.84	29.98	.....	82.7	−0.3	97	24	91	70	2	74	23		.....	.....	....	0.82	.....	4	4,786	s.	26	se.	1	12	13	6	4.6	0.0	0.0
Palestine	510	64	72	29.46	29.98	+.01	82.8	+0.6	100	25	93	66	20	73	23		72	68	68	1.04	−2.0	7	4,675	s.	22	ne.	21	5	22	4	5.4	0.0	0.0
Port Arthur	34	58	66	29.95	29.99	.....	81.1	.....	96	24	88	68	1	75	20		75	73	82	4.90	.....	16	6,532	sw.	30	ne.	31	12	13	6	4.9	0.0	0.0
San Antonio	701	119	132	29.25	29.96	+.01	83.6	+1.2	99	15	94	65	21	73	25		72	67	66	2.54	+0.3	6	4,960	se.	48	se.	1	13	15	3	4.1	0.0	0.0
Taylor	582	55	63	29.40	30.01	+.05	83.2	+0.5	99	31	94	65	21	73	26		.....	.....	....	1.22	−1.4	4	5,667	s.	32	s.	8	9	18	4	4.7	0.0	0.0

TABLE I.—*Climatological data for weather bureau stations, July, 1923*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.								Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
	Ft.	Ft.	Ft.	Ft.	Ft.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	N	In.	In.		Miles.							0–10	In.	In.
Ohio Valley and Tennessee.							**76.2**	**−0.4**									**70**	**3.86**	**−0.2**									**5.0**		
Chattanooga	762	189	213	29.21	30.01	−.01	77.0	−1.4	92	12	86	57	1	68	24	69	66	73	6.31	+2.4	9	4,140	sw.	37	sw.	8	5	21	5	5.5	0.0	0.0
Knoxville	996	102	111	28.97	30.00	−.02	76.6	−0.5	93	12	86	54	1	67	28	69	67	76	5.32	+1.1	7	3,585	sw.	26	w.	24	2	10	19	7.5	0.0	0.0
Memphis	399	76	97	29.57	29.99	−.01	80.2	−0.5	94	12	88	62	1	73	21	72	70	73	3.65	+0.1	8	4,294	sw.	39	sw.	28	11	16	4	4.3	0.0	0.0
Nashville	546	168	191	29.44	30.01	.00	78.5	−0.6	94	15	88	55	1	69	25	70	67	74	2.13	−2.2	8	4,284	w.	43	ne.	7	11	15	5	4.8	0.0	0.0
Lexington	989	193	230	28.97	30.01	.00	76.6	0.0	90	15	86	56	1	68	26	....	....	....	5.01	+0.6	12	6,979	sw.	44	nw.	24	13	13	5	4.4	0.0	0.0
Louisville	525	219	255	29.44	30.02	+.02	78.3	−0.3	93	15	88	57	1	69	26	68	64	67	4.05	+0.3	9	5,609	ne.	48	nw.	12	10	14	7	4.5	0.0	0.0
Evansville	431	139	175	29.54	30.00	.00	80.2	+0.9	96	15	90	58	1	70	25	70	65	63	1.00	−2.8	6	5,570	w.	30	nw.	5	7	20	4	4.7	0.0	0.0
Indianapolis	822	194	230	29.14	30.01	+.02	76.2	+0.5	94	21	86	56	1	67	26	66	61	64	2.43	−1.7	8	6,370	ne.	40	nw.	3	12	12	7	4.4	0.0	0.0
Royal Center	736	11	55	29.23	30.01	.....	73.2	.....	94	21	85	51	1	62	33	....	....	....	3.30	.....	8	5,173	sw.	40	nw.	15	9	12	10	5.0	0.0	0.0
Terre Haute	575	96	129	29.39	29.99	.....	77.6	.....	96	21	88	55	1	67	27	67	62	63	0.59	.....	7	5,183	sw.	28	e.	7	5	23	3	5.0	0.0	0.0
Cincinnati	628	11	51	29.34	30.00	.00	75.6	+0.5	92	20	87	51	1	64	30	....	64	68	2.51	−1.0	10	3,685	ne.	32	n.	6	9	17	5	4.5	0.0	0.0
Columbus	824	179	222	29.16	30.01	+.01	74.8	0.0	92	21	85	55	1	65	26	65	61	67	4.09	+0.4	14	5,756	e.	50	nw.	6	11	10	10	5.0	0.0	0.0
Dayton	899	137	173	29.06	29.99	.....	75.8	−0.4	94	21	87	53	1	65	29	66	61	65	1.50	−1.8	11	5,221	ne.	42	w.	5	16	12	3	3.8	0.0	0.0
Elkins	1,947	59	67	28.03	30.02	+.01	69.0	−1.5	86	10	81	47	1	57	32	63	61	83	3.73	−0.9	11	2,465	w.	24	sw.	22	5	15	11	5.9	0.0	0.0
Parkersburg	638	77	84	29.38	30.03	+.02	74.7	−0.9	93	10	86	53	1	64	30	67	64	75	5.52	+0.9	10	2,782	se.	30	nw.	7	12	9	10	5.2	0.0	0.0
Pittsburgh	842	353	410	29.13	30.01	+.01	73.3	−1.3	91	10	83	56	1	64	30	64	60	68	6.74	+2.3	12	5,841	nw.	53	nw.	6	8	10	13	6.0	0.0	0.0
Lower Lake Region.							**70.7**	**−0.8**									**65**	**1.95**	**−1.4**									**4.7**		
Buffalo	767	247	280	29.20	30.02	+.05	69.8	0.0	85	18	77	56	26	63	22	62	57	65	0.71	−2.7	8	7,694	sw.	29	w.	26	8	16	7	5.3	0.0	0.0
Canton	448	10	61	29.52	29.99	.....	66.2	−4.3	88	20	78	42	23	55	32	....	....	....	1.18	−2.0	8	5,050	sw.	33	e.	6	19	8	4	3.5	0.0	0.0
Oswego	335	76	91	.....	30.00	+.04	67.8	−2.6	84	20	75	54	24	60	24	....	....	....	0.62	−2.6	9	5,109	s.	25	ne.	25	12	9	10	....	0.0	0.0
Rochester	523	86	102	29.46	30.02	+.05	70.0	−0.7	90	20	80	51	26	60	28	61	55	63	1.97	−1.1	7	4,433	ne.	23	sw.	3	11	11	9	5.0	0.0	0.0
Syracuse	597	97	113	29.39	30.03	+.06	69.0	−1.8	88	20	78	50	23	60	27	....	....	....	2.78	−0.9	10	5,369	s.	26	nw.	25	8	14	9	5.5	0.0	0.0
Erie	714	130	166	29.25	30.01	+.03	70.8	−0.2	88	20	79	55	26	63	24	63	57	62	0.93	−2.3	11	7,368	n.	37	se.	30	14	10	7	4.6	0.0	0.0
Cleveland	762	190	201	29.21	30.02	+.03	71.2	−0.2	86	10	78	57	1	64	23	63	57	63	2.09	−1.5	11	7,188	ne.	37	nw.	6	10	11	10	5.4	0.0	0.0
Sandusky	629	62	70	29.35	30.02	+.03	73.0	−0.4	92	10	80	57	1	66	23	....	....	....	2.32	−1.5	12	4,443	ne.	38	n.	10	9	11	11	5.1	0.0	0.0
Toledo	628	208	243	29.35	30.02	+.03	73.2	0.0	93	10	82	59	17	64	26	64	60	66	2.77	−0.5	11	7,470	sw.	42	n.	10	18	6	7	3.8	0.0	0.0
Fort Wayne	856	113	124	29.11	30.02	.....	73.9	+0.4	93	10	84	52	1	64	31	65	61	68	5.26	.....	10	4,324	sw.	33	ne.	11	12	11	8	4.6	0.0	0.0
Detroit	730	218	258	29.24	30.02	+.04	72.6	+0.5	93	21	81	59	27	64	24	65	61	71	4.14	+0.7	10	5,850	e.	41	n.	10	15	8	8	4.4	0.0	0.0
Upper Lake Region.							**68.8**	**+0.8**									**72**	**3.41**	**+0.3**									**4.7**		
Alpena	609	13	92	29.37	30.04	+.07	66.2	+0.3	95	20	76	52	8	57	33	61	57	74	3.08	0.0	8	6,110	se.	38	nw.	30	13	6	12	5.2	0.0	0.0
Escanaba	612	54	60	29.36	30.02	+.05	66.5	0.0	89	19	74	51	3	59	26	63	60	81	6.62	+3.3	13	5,531	s.	36	ne.	29	12	9	10	5.0	0.0	0.0
Grand Haven	632	54	89	29.33	29.99	+.01	69.7	+1.0	89	31	79	51	1	60	28	64	59	68	1.44	−1.1	8	5,390	w.	25	nw.	28	13	14	4	4.1	0.0	0.0
Grand Rapids	707	70	87	29.26	30.01	+.03	73.4	+0.8	93	21	84	**54**	**29**	62	30	64	58	61	0.95	−1.7	6	3,238	e.	17	w.	21	8	14	9	5.0	0.0	0.0
Houghton	684	62	99	29.28	30.00	+.04	66.0	+0.7	88	31	76	48	28	56	31	....	....	....	3.89	+0.8	12	5,892	e.	28	n.	13	8	14	9	5.5	0.0	0.0
Lansing	878	11	62	29.08	30.01	.....	70.6	−0.5	92	20	83	52	17	58	36	64	62	78	4.76	+1.5	9	2,236	ne.	16	sw.	6	15	10	6	4.4	0.0	0.0
Ludington	637	60	66	29.33	30.02	.....	67.6	.....	85	31	76	51	4	59	26	62	57	68	0.51	.....	6	5,124	s.	20	s.	9	17	10	4	3.5	0.0	0.0
Marquette	734	77	111	29.24	30.04	+.08	65.0	+0.1	94	19	74	48	27	56	30	59	55	73	4.11	+1.0	15	4,507	e.	20	sw.	9	6	14	11	6.1	0.0	0.0
Port Huron	638	70	120	29.33	30.02	+.04	69.8	+1.0	93	20	78	53	26	61	29	63	58	70	1.48	+1.3	10	5,854	ne.	29	n.	10	14	13	4	3.8	0.0	0.0
Saginaw	641	69	77	29.34	30.02	.....	70.3	.....	93	20	81	54	1	60	32	64	61	73	4.25	+0.6	10	4,269	ne.	22	ne.	5	14	6	11	5.0	0.0	0.0
Sault Sainte Marie	614	11	52	29.35	30.04	+.07	65.3	**+3.4**	**90**	19	77	47	1	54	36	58	54	72	3.80	+1.0	8	3,831	w.	31	sw.	30	12	10	9	5.0	0.0	0.0
Chicago	823	140	310	29.15	30.01	+.03	74.4	+0.5	95	10	80	**62**	1	68	26	66	61	66	2.67	−1.0	8	6,193	e.	24	nw.	6	17	10	4	3.4	0.0	0.0
Green Bay	617	109	144	29.34	30.00	+.03	71.2	+1.7	95	9	81	55	1	62	32	64	60	71	3.31	−0.2	11	6,195	s.	42	n.	14	8	14	9	5.9	0.0	0.0
Milwaukee	681	125	139	29.28	30.02	+.05	71.4	+1.3	93	10	79	56	4	63	30	63	59	67	1.98	−1.0	5	4,610	ne.	30	se.	23	12	12	7	4.4	0.0	0.0
Duluth	1,133	11	47	28.80	30.00	+.05	64.6	+0.7	89	19	73	49	5	56	29	60	58	81	5.40	+1.8	14	6,545	ne.	45	nw.	22	13	10	8	4.9	0.0	0.0
North Dakota.							**72.4**	**+3.6**									**70**	**2.64**	**−0.3**									**5.2**		
Moorhead	940	50	58	28.95	29.94	.00	72.5	+4.4	93	19	83	52	2	62	28	66	62	72	2.34	−1.4	7	4,642	n.	33	sw.	31	7	16	8	5.7	0.0	0.0
Bismarck	1,674	8	57	28.23	29.97	+.04	73.3	+3.5	94	8	85	52	1	62	30	66	62	70	4.77	+2.6	12	6,007	se.	42	n.	8	8	14	9	5.3	0.0	0.0
Devils Lake	1,482	11	44	28.40	29.94	+.01	71.8	+3.7	97	18	84	46	30	59	35	64	60	69	2.07	−1.7	9	5,423	se.	37	ne.	8	18	8	5	4.0	0.0	0.0
Ellendale	1,457	10	56	28.42	29.96	.....	71.5	.....	92	19	82	52	30	61	29	....	....	....	3.62	.....	10	7,361	se.	43	nw.	5	8	15	8	5.4	0.0	0.0
Grand Forks	835	12	89	.....	.....	.....	72.1	.....	96	18	84	49	2	60	32	....	....	....	3.46	.....	12	.....	sw.	60	se.	22	13	9	9	.....	0.0	0.0
Williston	1,878	41	48	27.98	29.91	−.01	71.8	+2.9	94	21	84	43	30	60	42	63	59	68	1.38	−0.6	11	5,285	se.	36	sw.	17	7	16	8	5.5	0.0	0.0
Upper Mississippi Valley.							**77.6**	**+2.3**									**66**	**1.79**	**−1.9**									**4.4**		
Minneapolis	918	102	208	28.99	29.95	.....	76.0	.....	97	9	86	56	28	66	28	....	....	....	3.12	−0.7	6	6,506	s.	36	n.	10	9	11	11	5.3	0.0	0.0
St. Paul	837	236	261	29.09	29.98	+.03	75.2	+3.1	96	22	86	54	28	65	28	....	....	....	2.51	−0.9	7	6,335	se.	52	nw.	29	15	14	2	3.7	0.0	0.0
La Crosse	714	11	48	29.23	29.98	+.02	76.2	+3.4	98	23	88	53	1	64	33	....	....	....	0.62	−3.4	7	2,639	se.	17	w.	29	13	8	10	5.1	0.0	0.0
Madison	974	70	78	28.99	30.00	+.03	74.2	+2.1	93	21	84	55	1	65	26	66	61	68	2.28	−1.7	9	4,618	s.	31	ne.	22	7	16	8	5.2	0.0	0.0
Wausau	1,247	4	....	28.72	30.03	.....	69.8	.....	91	9	80	50	28	59	30	....	....	....	3.36	.....	11	.....	e.	....	....	17	9	5	3	3.9	0.0	0.0
Charles City	1,015	10	49	28.94	29.98	+.02	76.3	+2.8	96	23	88	52	28	64	33	68	63	68	3.30	−0.3	10	3,419	se.	23	ne.	22	15	14	2	3.4	0.0	0.0
Davenport	606	71	79	29.34	29.99	+.02	78.4	+3.1	99	22	89	58	1	68	29	68	64	65	1.76	−1.8	5	3,946	e.	25	s.	23	11	16	4	4.4	0.0	0.0
Des Moines	861	84	97	29.08	29.96	.00	78.2	+2.8	98	23	89	57	1	68	30	69	64	65	0.78	−3.1	5	3,778	sw.	22	sw.	5	11	14	6	5.0	0.0	0.0
Dubuque	698	81	96	29.27	30.01	+.04	76.8	+2.7	96	22	87	55	1	66	32	67	62	66	1.67	−2.6	7	3,187	s.	19	n.	10	7	18	6	5.4	0.0	0.0
Keokuk	614	64	78	29.33	30.00	+.02	78.8	+1.9	97	22	89	61	1	69	31	68	63	61	1.61	−2.4	4	3,676	ne.	23	w.	11	13	8	10	5.0	0.0	0.0
Cairo	358	87	93	29.61	29.98	−.02	79.8	+0.2	96	24	89	59	1	71	22	71	68	72	2.01	−1.4	6	3,932	s.	22	nw.	12	8	14	9	5.7	0.0	0.0
Peoria	609	11	45	29.35	30.01	+.03	77.6	+2.2	98	22	90	**54**	2	66	34	68	63	65	1.35	−1.6	6	2,818	ne.	16	w.	3	22	6	3	2.2	0.0	0.0
Springfield, Ill.	644	10	91	29.31	29.97	−.01	78.8	+2.3	98	22	89	57	1	69	28	69	64	65	1.31	−1.6	6	4,403	sw.	22	se.	30	15	12	4	4.0	0.0	0.0
Hannibal	534	74	109	29.42	29.98	.00	78.2	+1.4	96	22	89	60	29	68	32	....	....	....	0.87	−2.9	6	4,528	sw.	27	nw.	11	17	9	5	3.8	0.0	0.0
St. Louis	567	265	303	29.38	29.97	−.02	80.6	+2.0	95	15	89	62	1	72	21	70	65	62	1.83	−1.6	7	6,341	s.	27	s.	16	12	15	4	4.4	0.0	0.0
Missouri Valley.							**78.0**	**+2. 2**									**68**	**2.79**	**−1. 0**								**4.6**			
Columbia, Mo.	781	11	84	29.16	29.98	.00	77.3	−0.1	94	11	88	58	29	67	27	....	....	....	3.71	+0.1	7	3,609	e.	23	nw.	11	14	9	8	4.3	0.0	0.0
Kansas City	963	161	181	28.96	29.96	−.01	79.3	+1.8	97	11	88	60	2	71	24	70	65	66	3.40	−1.4	10	5,323	e.	36	nw.	12	15	13	3	4.0	0.0	0.0
St. Joseph	967	11	49	28.95	29.95	.....	79.2	.....	96	10	89	58	2	69	29	69	65	67	2.24	.....	8	4,000	se.	22	n.	27	18	11	2	3.1	0.0	0.0
Springfield, Mo.	1,324	98	104	28.62	29.99	+.01	77.2	+0.8	95	24	86	57	1	69	23	70	68	76	2.67	−2.1	8	5,087	se.	21	nw.	27	23	5	3	2.8	0.0	0.0
Iola	984	11	50	28.94	29.95	−.02	80.2	+2.1	102	24	92	61	2	69	31	....	....	....	2.64	−1.3	4	3,064	s.	18	nw.	12	11	15	5	4.7	0.0	0.0
Topeka	987	92	107	.....	.....	.....	79.0	+1.4	98	11	89	60	2	69	30	....	....	....	2.89	−2.0	11	5,121	se.	32	nw.	12	15	7	9	4.4	0.0	0.0
Drexel	1,299	10	54	28.61	29.96	.....	77.2	.....	96	23	88	54	28	67	31	....	....	....	1.29	.....	7	5,662	s.	32	ne.	10	6	17	8	5.4	0.0	0.0
Lincoln	1,189	11	84	28.73	29.95	.00	78.8	+2.4	98	10	88	56	2	69	28	68	64	64	1.88	−2.0	6	5,929	s.	26	n.	27	4	18	9	5.9	0.0	0.0
Omaha	1,105	115	122	28.82	29.97	+.02	79.5	+2.8	99	10	89	60	1	70	25	70	65	67	0.86	−3.5	6	4,082	se.	25	n.	27	13	13	5	4.3	0.0	0.0
Valentine	2,598	47	54	27.30	29.96	+.03	76.0	+2.3	98	9	87	55	1	65	36	66	61	66	4.01	+0.6	17	6,715	s.	44	w.	5	6	20	5	5.1	0.0	0.0
Sioux City	1,135	94	164	28.79	29.96	+.01	77.6	+3.3	99	23	88	55	28	68	31	68	64	66	2.93	−0.7	12	6,744	s.	36	s.	31	11	16	4	4.5	0.0	0.0
Huron	1,306	59	74	28.60	29.96	+.02	75.2	+3.4	97	9	86	51	1	64	32	68	64	72	4.17	+1.2	11	5,658	se.	39	nw.	10	10	15	6	5.1	0.0	0.0
Pierre	1,572	70	75	28.30	29.92	−.01	77.0	+1.7	99	8	88	57	1	66	36	69	65	69	2.67	+0.3	11	5,675	se.	42	n.	4	11	13	7	5.0	0.0	0.0
Yankton	1,233	49	57	28.66	29.94	.00	78.2	+4.1	99	9	88	58	1	68	32	....	....	....	1.68	−1.8	11	4,488	se.	26	s.	31	6	20	5	5.2	0.0	0.0

TABLE I.—*Climatological data for weather bureau stations, July, 1923*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.		°F.	°F.	*N*	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
Northern Slope.							**70.9**	**+3.0**											**62**	**2.46**	**+0.9**									**4.3**		
Billings	3,140	5	....	....	....	.....	74.8	.....	102	21	91	53	3	59	41	....	....	....	....	2.41	.....	10	.....	nw.	....	.....	....	12	14	5	....	0.0	0.0
Havre	2,505	11	44	27.34	29.92	+.01	71.2	+2.9	96	21	84	47	31	59	38	63	58	69	4.33	+2.4	14	3,582	e.	37	sw.	15	18	8	5	3.9	0.0	0.0
Helena	4,110	87	112	25.82	29.92	−.01	69.8	+4.1	93	19	83	47	31	57	37	57	49	54	1.35	+0.3	11	5,801	sw.	34	sw.	12	15	11	5	4.3	0.0	0.0
Kalispell	2,973	48	56	26.90	29.89	−.04	68.0	+3.7	94	23	81	45	4	55	36	56	48	55	1.60	+0.8	8	4,322	nw.	26	sw.	17	20	8	3	3.4	0.0	0.0
Miles City	2,371	48	55	27.44	29.92	.00	77.4	+4.5	102	21	89	56	30	66	38	65	59	58	2.51	+1.1	13	4,653	se.	33	se.	3	16	12	3	3.8	0.0	0.0
Rapid City	3,259	50	58	26.64	29.97	+.04	72.7	+2.5	95	7	84	54	2	62	33	63	58	63	2.25	−0.3	13	4,722	se.	32	sw.	5	12	11	8	5.0	0.0	0.0
Cheyenne	6,088	84	101	24.13	29.95	+.03	67.5	+0.8	85	30	79	49	5	56	35	58	54	69	3.23	+1.2	15	6,428	s.	43	w.	28	9	20	2	4.8	0.0	0.0
Lander	5,372	60	68	24.72	29.93	+.01	71.2	+3.2	93	20	85	51	6	58	36	59	53	60	2.26	+1.4	12	3,766	sw.	54	sw.	6	10	16	5	5.1	0.0	0.0
Sheridan	3,790	10	47	26.13	29.89	.....	72.9	.....	98	17	87	52	30	59	39	62	57	64	6.37	.....	15	3,586	se.	30	se.	6	15	11	5	4.1	0.0	0.0
Yellowstone Park	6,200	11	48	23.98	29.96	+.04	64.0	+2.5	89	20	79	44	6	49	39	52	45	59	0.95	−0.2	13	4,806	s.	37	s.	30	12	15	4	4.3	0.0	0.0
North Platte	2,821	11	51	27.12	29.99	+.03	75.9	+3.0	95	7	87	55	1	65	30	67	64	72	3.63	+1.0	7	4,173	s.	21	n.	31	14	12	5	4.1	0.0	0.0
Middle Slope.							**78.4**	**+1.5**											**61**	**2.38**	**−0.6**									**4.2**		
Denver	5,292	106	113	24.82	29.96	+.05	72.6	+0.4	93	30	84	55	1	61	35	59	52	57	2.74	+1.1	14	5,095	s.	38	nw.	28	7	22	2	4.8	0.0	0.0
Pueblo	4,685	80	86	25.36	29.94	+.03	75.0	+0.8	96	31	88	55	1	62	39	61	55	60	4.05	+2.1	10	3,785	e.	40	nw.	31	6	24	1	4.7	0.0	0.0
Concordia	1,392	50	58	28.51	29.94	−.01	78.8	+0.7	98	23	89	59	28	69	31	69	65	67	4.48	+0.9	9	4,742	s.	25	s.	11	9	19	3	4.8	0.0	0.0
Dodge City	2,509	11	51	27.43	29.96	+.03	79.3	+0.9	102	31	91	60	1	67	32	67	62	63	1.95	−1.4	9	6,329	s.	35	sw.	4	19	11	1	2.6	0.0	0.0
Wichita	1,358	139	158	28.54	29.93	−.03	80.8	+1.8	102	24	91	62	1	71	29	70	65	62	0.89	−2.7	6	7,658	s.	29	s.	4	11	16	4	3.9	0.0	0.0
Broken Arrow	765	11	52	29.16	29.97	.....	81.2	.....	100	24	92	64	2	71	33	....	....	....	1.17	.....	3	6,102	s.	52	nw.	15	9	19	3	4.9	0.0	0.0
Muskogee	652	4	....	....	....	.....	84.0	.....	105	24	97	61	1	71	38	....	....	....	0.63	.....	3	....	s.	....	....	....	16	15	0	....	0.0	0.0
Oklahoma City	1,214	10	47	28.69	29.94	−.02	84.0	+4.2	105	31	96	62	1	72	29	70	64	58	0.15	−3.5	2	5,654	s.	25	nw.	12	14	16	1	4.0	0.0	0.0
Southern Slope.							**81.2**	**+0.7**											**54**	**1.80**	**−0.7**									**4.2**		
Abilene	1,738	10	52	28.17	29.92	−.01	83.8	+1.6	103	31	95	62	1	72	29	68	61	53	0.22	−2.2	4	5,638	s.	25	se.	21	8	21	2	5.0	0.0	0.0
Amarillo	3,676	10	49	26.33	29.96	+.04	78.3	+2.2	101	31	90	61	22	66	33	65	59	58	1.85	−1.3	7	6,432	se.	32	ne.	29	16	15	0	3.5	0.0	0.0
Del Rio	944	64	71	28.96	29.93	+.03	84.2	−0.5	100	15	94	63	21	74	27	....	....	....	2.52	+0.3	4	6,601	se.	50	ne.	19	18	9	4	3.9	0.0	0.0
Roswell	3,566	75	85	26.38	29.90	+.02	78.5	−0.4	100	30	91	60	22	66	34	63	54	51	2.59	+0.4	8	5,378	se.	39	nw.	1	11	17	3	4.4	0.0	0.0
Southern Plateau.							**78.8**	**−0.1**											**44**	**0.67**	**−0.5**									**3.3**		
El Paso	3,762	110	133	26.17	29.82	−.02	82.1	+1.6	100	16	93	62	22	71	27	63	52	42	0.20	−1.9	6	7,301	se.	33	se.	21	20	10	1	3.2	0.0	0.0
Sante Fe	7,013	38	53	23.38	29.88	.00	69.7	+0.7	91	30	82	51	22	57	32	54	46	49	2.06	−0.6	13	4,055	e.	24	ne.	1	8	19	4	4.9	0.0	0.0
Flagstaff	6,908	10	59	23.46	29.86	+.03	65.8	+0.8	89	1	80	46	9	52	39	52	....	55	1.08	.....	9	5,058	w.	29	w.	31	11	19	1	....	0.0	0.0
Phoenix	1,108	11	81	28.68	29.79	+.01	89.2	−1.2	111	2	102	71	6	77	36	70	61	46	0.77	−0.3	5	4,086	e.	32	se.	12	10	17	4	4.4	0.0	0.0
Yuma	141	9	54	29.63	29.77	+.01	89.8	−1.0	111	2	103	67	9	76	41	71	61	45	0.28	+0.2	2	4,198	sw.	32	e.	30	21	7	3	2.6	0.0	0.0
Independence	3,967	5	25	25.91	29.85	+.02	77.2	−1.3	103	29	94	50	17	61	39	56	38	30	0.05	−0.1	1	6,183	se.	36	se.	6	26	4	1	1.5	0.0	0.0
Middle Plateau.							**74.5**	**+2.0**											**37**	**0.36**	**−0.1**									**3.3**		
Reno	4,532	74	81	25.47	29.87	.00	71.0	+3.5	101	28	88	42	7	54	42	52	37	38	0.03	−0.1	1	5,401	w.	36	w.	6	27	3	1	1.5	0.0	0.0
Tonopah	6,090	12	20	24.09	29.85	.....	74.1	.....	95	29	85	55	7	63	30	52	33	26	0.27	0.0	0	6,868	se.	31	se.	6	20	9	2	2.8	0.0	0.0
Winnemucca	4,344	18	56	25.59	29.89	−0.1	72.2	+1.6	100	27	90	38	7	55	48	53	38	36	0.24	+0.1	2	4,435	sw.	32	nw.	4	21	8	2	2.5	0.0	0.0
Modena	5,479	10	43	24.66	29.87	+0.1	72.0	+2.3	96	29	87	49	10	56	44	52	37	36	0.81	−0.4	5	8,559	sw.	48	s.	6	16	11	4	3.8	0.0	0.0
Salt Lake City	4,360	163	203	25.61	29.87	−.03	78.3	+2.6	95	30	89	62	2	68	31	59	48	39	0.21	−0.3	5	6,082	se.	33	s.	30	14	7	10	4.4	0.0	0.0
Grand Junction	4,602	60	68	25.39	29.88	−.01	79.2	0.0	99	30	92	59	8	66	36	61	51	45	0.62	+0.1	9	4,550	se.	30	nw.	31	7	19	5	4.8	0.0	0.0
Northern Plateau.							**73.5**	**+2.6**											**47**	**0.74**	**+0.3**									**3.6**		
Baker	3,471	48	53	26.44	29.96	+.01	67.4	+2.4	96	22	82	42	5	52	44	56	48	57	0.60	+0.2	6	4,231	se.	22	sw.	13	10	16	5	4.1	0.0	0.0
Boise	2,739	78	86	27.10	29.88	−.05	75.4	+2.5	100	27	90	49	5	60	39	59	47	43	0.68	+0.5	5	3,568	nw.	30	se.	13	22	6	3	2.5	0.0	0.0
Lewiston	757	40	48	29.11	29.90	−.05	76.8	+3.2	104	22	92	53	8	62	44	....	....	....	1.10	+0.7	8	2,831	e.	23	nw.	2	16	10	5	3.5	0.0	0.0
Pocatello	4,477	60	68	25.48	29.88	−.04	73.5	+2.3	97	21	88	51	4	60	36	56	46	45	0.95	+0.3	6	5,223	se.	40	s.	24	15	9	7	4.4	0.0	0.0
Spokane	1,929	101	110	27.91	29.91	−.05	72.0	+3.0	99	22	86	50	8	58	37	57	46	47	0.77	+0.1	7	4,185	sw.	25	w.	30	14	15	2	3.5	0.0	0.0
Walla Walla	991	57	65	28.86	29.90	−.07	76.0	+1.9	102	22	88	52	8	64	36	59	47	41	0.33	−0.1	7	3,476	s.	20	sw.	15	16	11	4	3.4	0.0	0.0
North Pacific Coast Region.							**63.7**	**+1.4**											**76**	**1.16**	**+0.5**									**4.9**		
North Head	211	11	56	29.84	30.06	−.02	59.0	+1.3	69	13	62	52	13	56	17	56	55	87	1.31	+0.8	6	10,758	n.	39	n.	12	8	14	9	6.0	0.0	0.0
Port Angeles	29	8	53	30.02	30.05	.....	58.6	.....	81	14	66	45	26	51	29	....	....	....	1.23	+0.8	5	5,193	sw.	21	w.	4	16	4	11	4.5	0.0	0.0
Seattle	125	215	250	29.92	30.05	+.01	64.4	+0.9	88	14	73	52	23	56	28	57	52	70	0.68	0.0	4	5,716	n.	28	s.	1	14	7	10	4.8	0.0	0.0
Tacoma	213	113	120	29.80	30.02	−.04	65.4	+2.0	92	14	75	52	23	56	31	....	....	....	0.76	+0.1	5	5,350	n.	24	w.	1	9	14	8	5.4	0.0	0.0
Tatoosh Island	86	9	57	.....	30.04	−.01	56.8	+1.7	77	13	61	49	20	53	25	....	....	94	1.38	−0.4	6	6,620	sw.	38	sw.	2	4	6	21	....	0.0	0.0
Yakima	1,071	5	....	....	....	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	....	....	....	....	....	....	....	....	....	....	....	....
Medford	1,425	4	....	....	....	.....	72.8	.....	102	28	92	48	2	54	47	....	....	....	0.59	.....	7	.....	nw.	....	.....	....	17	9	5	....	0.0	0.0
Portland, Oreg.	153	68	106	29.86	30.02	−.03	67.8	+1.1	93	13	78	52	31	58	28	60	54	66	2.17	+1.6	5	4,023	nw.	16	n.	30	12	7	12	5.0	0.0	0.0
Roseburg	510	9	57	29.48	30.02	−.01	68.6	+1.2	96	29	82	49	5	56	40	58	52	63	0.59	+0.3	3	2,676	n.	15	w.	14	15	11	5	3.5	0.0	0.0
Middle Pacific Coast Region.							**65.4**	**+0.7**											**64**	**0.02**	**0.0**									**2.9**		
Eureka	62	73	89	29.99	30.06	+.01	58.2	+2.9	68	2	62	49	31	54	13	55	53	86	0.03	−0.1	2	4,643	n.	27	n.	5	5	13	13	6.4	0.0	0.0
Point Reyes	490	7	18	29.42	29.94	.....	54.6	+0.9	66	15	59	46	2	50	13	....	....	....	0.05	.....	1	17,382	nw.	66	nw.	4	8	13	10	5.9	0.0	0.0
Red Bluff	332	50	56	29.52	29.86	−.03	80.1	−0.7	112	28	95	57	16	65	40	60	45	36	0.00	0.0	0	3,778	se.	19	se.	1	31	0	0	0.6	0.0	0.0
Sacramento	69	106	117	29.81	29.88	.00	73.6	+0.4	108	27	90	53	9	58	41	60	50	55	0.00	0.0	0	6,756	s.	22	s.	6	31	0	0	0.2	0.0	0.0
San Francisco	155	208	243	29.79	29.96	+.01	60.8	+2.3	82	27	67	51	1	54	28	55	52	79	0.00	0.0	0	8,086	w.	34	w.	8	24	6	1	2.6	0.0	0.0
San Jose	141	12	110	29.82	29.97	.....	65.2	−1.7	97	27	79	47	25	51	45	....	....	....	0.00	0.0	0	4,746	nw.	21	nw.	6	24	7	0	1.7	0.0	0.0
South Pacific Coast Region.							**70.1**	**−0.6**											**66**	**0.00**	**0.0**									**2.4**		
Fresno	327	89	98	29.52	29.86	+.03	79.8	−2.2	107	27	96	56	17	63	38	60	45	36	0.00	0.0	0	6,592	nw.	26	nw.	2	30	1	0	0.5	0.0	0.0
Los Angeles	338	159	191	29.56	29.92	+.02	70.0	−0.2	85	20	80	56	10	61	24	61	57	72	T.	0.0	0	3,820	sw.	17	sw.	14	22	7	2	2.7	0.0	0.0
San Diego	87	62	70	29.82	29.91	−.01	67.0	−0.2	77	23	72	58	16	62	15	62	60	83	0.01	0.0	1	4,573	w.	19	s.	5	13	14	4	4.3	0.0	0.0
San Luis Obispo	201	32	40	29.75	29.97	+.02	63.6	+0.4	86	28	76	47	25	51	33	55	50	72	0.00	0.0	0	2,994	nw.	16	nw.	16	25	6	0	2.2	0.0	0.0
West Indies.																																
San Juan, P. R.	82	9	54	29.96	30.04	.....	79.6	.....	87	22	84	72	1	75	13	....	....	....	2.74	−3.7	21	10,010	e.	34	e.	27	7	16	8	5.7	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.71	29.83	−.01	80.8	+0.4	91	14	87	70	27	74	17	75	74	85	3.15	−4.2	14	5,670	nw.	26	s.	28	0	17	14	7.3	0.0	0.0
Colon	36	7	97	29.80	29.84	−.02	81.6	+1.3	89	14	80	70	28	77	13	77	76	83	10.33	−5.2	19	7,611	n.	26	nw.	16	0	8	23	8.3	0.0	0.0
Alaska.																																
Juneau	80	11	54	29.97	30.06	.....	59.4	.....	82	7	68	47	15	51	32	55	51	74	4.10	.....	13	4,408	s.	25	nw.	15	9	8	14	6.4	0.0	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, July, 1923.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
St. Johns, N. F	125	29.74	29.87	−0.10	59.4	+0.1	67.6	51.3	83	44	5.07	+1.18	0.0
Sydney, C. B.I	48	29.92	29.97	+.04	61.7	−0.6	70.9	52.5	83	44	5.10	+1.45	0.0
Halifax, N. S	88	29.87	29.97	+.01	62.9	−0.5	72.1	53.8	89	45	4.43	+0.38	0.0
Yarmouth, N. S	65	29.90	29.97	+.02	58.5	−1.0	66.2	50.8	75	46	2.10	−1.52	0.0
Charlottetown, P. E. I	38	29.89	29.93	+.03	62.4	−1.7	69.1	55.8	81	47	1.14	−2.35	0.0
Chatham, N. B	28	29.84	29.87	−.01	62.8	−2.2	73.3	52.2	88	44	3.25	−0.94	0.0
Father Point, Que	20	29.91	29.93	+.08	53.5	−4.1	62.1	45.0	73	34	2.00	−1.04	0.0
Quebec, Que	296	29.67	29.99	+.08	65.1	−0.4	74.8	55.4	88	45	0.72	−3.54	0.0
Montreal, Que	187	29.77	29.97	+.04	67.7	−0.8	76.8	58.6	85	50	3.81	−0.48	0.0
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.74	30.00	+.06	67.6	−1.9	78.9	56.4	90	48	3.19	−0.28	0.0
Kingston, Ont	285	29.70	30.00	+.03	67.6	−0.6	75.7	59.5	84	50	0.32	−2.57	0.0
Toronto, Ont	379	29.60	29.99	+.02	68.9	+0.9	78.8	59.1	92	51	1.72	−1.20	0.0
Cochrane, Ont	930				62.8		75.5	50.1	88	39	2.49		0.0
White River, Ont	1,244	28.70	29.99	+.05	59.9	+0.4	74.9	44.9	92	33	2.17	−0.63	0.0
Port Stanley, Ont	592												
Southampton, Ont	656				64.5	−0.2	75.1	53.8	84	49	0.79	−1.19	0.0
Parry Sound, Ont	688	29.32	30.00	+.04	68.7	+2.7	81.3	56.1	90	45	0.34	−2.28	0.0
Port Arthur, Ont	644	29.31	30.02	+.08	64.1	+2.1	73.2	55.1	95	44	2.90	−0.58	0.0
Winnipeg, Man	760	29.12	29.93	.00	71.4	+5.4	83.2	59.7	96	45	3.55	+0.47	0.0
Minnedosa, Man	1,690	28.18	29.96	+.03	66.2	+4.0	76.4	56.1	88	41	6.00	+3.40	0.0
Le Pas, Man	860				65.6		77.2	54.1	85	38	2.22		0.0
Qu'Appelle, Sask	2,115	27.72	29.92	.00	66.7	+3.2	77.1	56.3	88	42	7.14	+4.66	0.0
Medicine Hat, Alb	2,144												
Moose Jaw, Sask	1,759				68.2		80.5	56.0	90	44	2.89		0.0
Swift Current, Sask	2,392	27.40	29.96	+.05	67.6	+1.1	79.6	55.6	91	47	4.23	+1.79	0.0
Calgary, Alb	3,428												
Banff, Alb	4,521												
Edmonton, Alb	2,150												
Prince Albert, Sask	1,450	28.42	29.97	+.06	65.9	+4.0	77.2	54.6	87	44	2.92	+0.87	0.0
Battleford, Sask	1,592	28.22	29.93	+.03	66.2	+1.5	77.1	55.3	86	44	3.68	+1.34	0.0
Kamloops, B. C	1,262												
Victoria, B. C	230	29.76	30.01	−.04	59.9	−0.1	67.4	52.3	82	48	0.96	+0.56	0.0
Barkerville, B. C	4,180												
Triangle Island, B. C	680												
Prince Ruppert, B. C	170												
Hamilton, Ber	151												

LATE REPORTS.

May, 1923.													
Calgary, Alb	3,428	26.36	29.92	+.08	50.9	+1.9	65.0	36.9	79	22	5.38	+3.61	0.0
June, 1923.													
Kamloops, B. C	1,262	28.62	29.69	+.02	64.5	+0.7	76.3	52.7	90	42	3.12	+1.70	0.0
Calgary, Alb	3,428	26.36	29.87	+.03	58.1	+2.1	69.9	46.4	85	40	7.73	+5.28	0.0
Port Stanley, Ont	592	29.33	29.97	.00	63.4	−0.4	74.1	52.8	86	40	1.47	−1.26	0.0
Hamilton, Ber	151	29.97	30.13	+.01	74.1	−0.9	79.3	69.0	84	60	1.62	−4.33	0.0

SEISMOLOGICAL REPORTS FOR JULY, 1923.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, Sept. 3, 1923.]

TABLE 1.—*Noninstrumental earthquake reports, July, 1923.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1923.	*H. m.*		° ′	° ′			*Sec.*			
July 20	7 00	Valley Center	33 15	117 00	5	1		Rumbling	Felt by several	B. Amago.
20	20 15	San Diego	32 43	117 10	2	1	2	None	do	D. Blake.
22	11 15	Rialto	34 05	117 30	5	5				S. B. Millis.
23	7 30	Arrowhead Springs	34 20	117 15	5	1				U. S. V. Hospital 54.
	7 46	do	34 20	117 15	3	1				Do.
	7 32	Avalon	33 15	118 15						T. M. Polhamus.
		Balboa	33 50	117 50	5–6	2	30–50		Felt by everyone	A. Deraga.
	7 15	Barrett	32 30	116 45						F. Quaid.
	7 32	Calexico	32 41	115 30	2	1	5	None	Felt by several	H. B. Lewis.
	ca. 7 30	Chula Vista	32 30	117 10	3	1	3	do	do	N. B. Dittenhaver.
	7 32	Claremont	37 48	122 26	5–6	1	5	Rumbling	Nearly everyone awakened	S. H. Brackett.
		do	37 48	122 26	5	2	5, 10	do	Felt by many	F. P. Brackett.
	ca. 7 30	Compton	33 55	118 15	4	2	3, 2?	None	do	P. Hansen.
	7 30	Elsinore	33 37	117 15					More shocks during night	W. L. Wilhite.
	7 32	Fairmont	34 45	118 30	5	2		Rumbling	Felt by all	W. & C. Lane.
	7 30	Fontana	34 05	116 30	5	3	90, 40, 40	do	Felt by several	J. R. Lundems.
	7 31	Los Angeles	34 03	118 15	6	Several.	5–10	None	Felt by everyone	H. B. Hersey.
	7 34	do	34 03	118 15	6	3	1–2	do	Felt by many	R. F. Young.
	7 43	Llano	34 30	117 47	4		20–30	do		F. J. Lecher.
	7 30	Long Beach	33 45	118 15	5	1	10	Rumbling	Felt by many	G. D. West.
	7 31	do	33 45	118 15	5	1	11	None	do	J. M. Bartley.
	7 30	Oxnard	34 15	119 15						American Beet Sugar Co.
	7 28	Pasadena	34 05	118 10	6	2	2–3	Rumbling	Felt by many	W. P. Hoge.
	7 30	do	34 05	118 10	5	3	Brief.	do	do	M. S. Jones.
	7 30	Pomona	34 05	117 45	4	2	1, 4–5	Rattling	do	J. E. Adamson.
	7 32	San Diego	32 43	117 10	4	1	3	Rumbling	do	D. Blake.
	7 30	Highlands	34 10	117 15						S. Calif. Edison Co.
	7 28	Sierra Madre	34 15	118 10	3	2		Loud	Felt by many	Anita Gregory.
	7 30	Squirrel Inn			5	1	20		do	Mrs. S. W. Frantz.
	7 47	do			3	1	1			Do.
	7 30	Trona	35 45	117 20	3	2	5 *ca.*	Rattling	Felt by many	R. W. Mumford.
		Tustin	33 45	117 50						Irvine Co.
		Valley Center	33 15	117 00	5			Rumbling	Felt by several	B. Amago.
		Yorba Linda	33 50	117 45	4	1	8–10			P. J. Ton.
	20 30	Julian	33 05	116 37	4	2	2, 3	None	Felt by several	J. H. L. Vogt.
	20 46	Arrowhead Springs	34 20	117 15	3	1				U. S. V. Hospital 54.
25	11 27	Mount Wilson	34 13	118 16	1	2	1	None		W. P. Hoge.
28	18 30	San Bernardino	34 05	117 15	3	1				Mrs. S. W. Frantz.
29	16 10	Compton	33 55	118 15	3–4	2	Few.	None	Felt by several	P. Hansen.
		WASHINGTON.								
14	23 30	Silverton	48 05	121 40	4	2	30 *ca.*	Rumbling		H. S. Tusler.
15	0 10	Arlington	48 10	122 10	4	2	Several.	do	Felt by many	N. Field.
	1 45	do	48 10	122 10						Do.

TABLE 2.—*Instrumental seismological reports, July, 1923.*

[For significance of symbols and description of stations, see REVIEW for January, 1923.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

CALIFORNIA. *Theosophical University, Point Loma.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 2	.....	.....	15 00 00	.....	50	50	.....	Tremors during preceding 24 hours.
7	.....	.....	.....	.....	50	100	.....	
8	.....	.....	.....	.....	50	50	.....	
19	.....	.....	.....	.....	50	50	.....	
20	.....	.....	.....	.....	50	50	.....	
23	.....	.....	7 32 00	.....	1,000	900	.....	Light shock (II Rossi-Forel).

COLORADO. *Regis College, Denver.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 23	.....	P.....	7 32 ..	.....	.....	.....	.....	San Bernardino, Calif. P indistinct; S not recorded.
		L.....	7 34 ..	.....	.....	.....	.....	
		M.....	7 34 30	5–6	*15,000	*15,000	.....	
		C.....	7 37 ..	.....	.....	.....	.....	
		F.....	7 41 ..	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 7	.....	e.....	6 31 16	.....	.....	.....	.....	
		F.....	6 36 ..	.....	.....	.....	.....	
10	.....	e.....	0 48 ..	.....	.....	.....	.....	
		F.....	0 52 ..	.....	.....	.....	.....	
12	.....	eL.....	3 10 ..	18	.....	.....	.....	
		F.....	3 35 *ca.*	.....	.....	.....	.....	
13	.....	P.....	11 32 10	.....	.....	.....	.....	
		eL.....	12 05 ..	30	.....	.....	.....	
		L.....	12 15 ..	20	.....	.....	.....	
		F.....	12 40 ..	.....	.....	.....	.....	
17	.....	e.....	1 27 25	.....	.....	.....	.....	
		F.....	1 35 ..	.....	.....	.....	.....	
20	.....	P.....	15 14 00	.....	.....	.....	7,800	
		S.....	15 23 10	.....	.....	.....	.....	
		F.....	15 30 *ca.*	.....	.....	.....	.....	
22	.....	P.....	14 29 22	.....	.....	.....	7,900	
		S.....	14 38 35	.....	.....	.....	.....	Ll lost changing sheet.
		L.....	14 54 ..	20	.....	.....	.....	
		L.....	15 01 30	16	.....	.....	.....	
		F.....	15 30 *ca.*	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, July, 1923*—Continued.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington*—Contd.

1923. July 23	.....	S?.....	7 40 09	.....	.....	*11,000	.....	Small amplitudes on EW.
		$M1_N$...	7 48 ..	.....	.....	*11,000	.....	
		$M2_N$...	7 49 ..	.....	.....	*10,000	.....	
		F.....	8 05 *ca.*	.....	.....	.....	.....	

*Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
July 2	.....	e.....	2 51 02	.....	.....	.....	.....	
		eL....	3 25 20	28	.....	.....	.....	
		L.....	3 34 ..	22	.....	.....	.....	
		L.....	3 40 ..	16	.....	.....	.....	
		F.....	4 40 *ca.*	.....	.....	.....	.....	
4	.....	e.....	5 31 23	.....	.....	.....	.....	
		S?....	5 37 25	.....	.....	.....	.....	
		eL....	5 56 ..	16	.....	.....	.....	
		F.....	6 10 *ca.*	.....	.....	.....	.....	
4	.....	P.....	8 21 21	.....	.....	.....	5,400	
		S.....	8 28 23	.....	.....	.....	.....	
		eL....	8 37 ..	16	.....	.....	.....	
		F.....	9 50 *ca.*	.....	.....	.....	.....	
7	.....	e.....	6 24 13	.....	.....	.....	.....	
		S?....	6 28 18	.....	.....	.....	.....	
		eL....	6 39 ..	18	.....	.....	.....	
		F.....	7 *ca.* ..	.....	.....	.....	.....	
10	.....	.....	.....	.....	.....	.....	.....	Quake about 0:35 to 3:00; no time.
12	.....	.....	.....	.....	.....	.....	.....	Quake about 2:30; no time breaks.
12	.....	.....	.....	.....	.....	.....	.....	Quake about 8:30 to 10:30; no time.
13	.....	P.....	11 31 00	.....	.....	.....	5,100	
		S.....	11 37 50	.....	.....	.....	.....	
		L?....	11 45 00	25	.....	.....	.....	
		L.....	12 11 ..	20	.....	.....	.....	
		L.....	12 20 ..	16	.....	.....	.....	
		F.....	14 20 *ca.*	.....	.....	.....	.....	
14	.....	eL....	0 47 ..	20	.....	.....	.....	
		L.....	0 58 ..	18	.....	.....	.....	
		L.....	1 02 ..	15	.....	.....	.....	
		F.....	1 50 *ca.*	.....	.....	.....	.....	
16	.....	S.....	14 13 05	.....	.....	.....	9,200	P lost changing sheet.
		L.....	14 30 40	30	.....	.....	.....	
		L.....	14 34 ..	20	.....	.....	.....	
		L.....	14 38 ..	16	.....	.....	.....	
		F.....	16 20 *ca.*	.....	.....	.....	.....	
17	.....	S?.....	1 19 28	.....	.....	.....	.....	
		F.....	2 10 *ca.*	.....	.....	.....	.....	
18	.....	P.....	6 10 15	.....	.....	.....	4,600	
		S.....	6 16 35	.....	.....	.....	.....	
		L.....	6 22 35	18	.....	.....	.....	
		L.....	6 26 ..	14	.....	.....	.....	
		F.....	7 *ca.*	.....	.....	.....	.....	
20	.....	P?....	15 14 45	.....	.....	.....	8,400	
		S.....	15 24 33	.....	.....	.....	.....	
		L?....	15 38 40	.....	.....	.....	.....	
		F.....	16 20 ..	.....	.....	.....	.....	
22	.....	P.....	14 28 35	.....	.....	.....	6,800	
		S.....	14 36 54	.....	.....	.....	.....	
		L?....	14 48 20	22	.....	.....	.....	
		L.....	14 52 ..	16	.....	.....	.....	
		F.....	17 30 *ca.*	.....	.....	.....	.....	
23	.....	P.....	7 35 43	.....	.....	.....	2,700	
		S.....	7 40 00	.....	.....	.....	.....	
		L.....	7 42 15	.....	.....	.....	.....	
		F.....	9 10 *ca.*	.....	.....	.....	.....	
31	.....	P.....	5 45 00	.....	.....	.....	6,500	
		S.....	5 53 02	.....	.....	.....	.....	L faint.
		eL....	6 04 50	.....	.....	.....	.....	
		F.....	6 30 *ca.*	.....	.....	.....	.....	
31	.....	P.....	15 18 30	.....	.....	.....	6,900	
		S.....	15 26 54	.....	.....	.....	.....	
		eL....	15 39 ..	.....	.....	.....	.....	
		L.....	15 42 30	18	.....	.....	.....	
		L.....	15 50 ..	15	.....	.....	.....	
		F.....	17 40 *ca.*	.....	.....	.....	.....	

CANAL ZONE. *Panama Canal, Balboa Heights.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 13	.....	P.....	19 42 52	.....	.....	.....	*ca.* 240	Probably SW.
		S.....	19 43 18	.....	.....	.....	.....	
		L_E....	19 43 30	.....	.....	.....	.....	
		M_E....	19 43 34	.....	*2,000	.....	.....	
		M_N....	19 43 20	.....	.....	*2,000	.....	
		F_E....	19 48 25	.....	.....	.....	.....	
		F_N....	19 48 20	.....	.....	.....	.....	
14	.....	P_E....	13 55 52	.....	.....	.....	*ca.* 240	Do.
		P_N....	13 55 50	.....	.....	.....	.....	
		S_E....	13 56 18	.....	.....	.....	.....	
		S_N....	13 56 16	.....	.....	.....	.....	
		L_E....	13 56 32	.....	.....	.....	.....	
		L_N....	13 56 30	.....	.....	.....	.....	
		M_E....	13 56 36	.....	*4,000	.....	.....	
		M_N....	13 56 28	.....	.....	*4,000	.....	
		F_E....	14 01 00	.....	.....	.....	.....	
		F_N....	14 01 00	.....	.....	.....	.....	
30	.....	.....	.....	.....	.....	.....	.....	Very slight tremor between 10:57:40 and 11:00:00; probably local.

* Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 13	.....	eL....	12 10 ..	20	.....	.....	.....	
		F.....	12 20 ..	.....	.....	.....	.....	
22	.....	eL....	14 56 ..	16	.....	.....	.....	
		F.....	15 10 ..	.....	.....	.....	.....	
23	.....	e.....	7 45 ..	.....	.....	.....	.....	
		eL....	7 49 ..	16	.....	.....	.....	
		F.....	8 *ca.*	.....	.....	.....	.....	

CANADA. *Dominion Observatory, Ottawa.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
July 1	.....	eL....	8 49 ..	.....	.....	.....	.....	
		L.....	8 55 *to*	.....	.....	.....	.....	
			9 11 ..	18	.....	.....	.....	
		F.....	9 33 *ca*	.....	.....	.....	.....	
2	.....	e?.....	2 21 30	.....	.....	.....	(7,940)	L waves fairly sinusoidal; never great in amplitude; taper off rapidly in amplitude after about 4:15.
		e?.....	2 39 04	.....	.....	.....	.....	
		e?.....	2 51 00	.....	.....	.....	.....	
		O.....	(2 45 49)	.....	.....	.....	.....	
		eP?...	2 57 07	.....	.....	.....	.....	
		eS?....	3 06 24	9	.....	.....	.....	
		eL?...	3 21 30	43	.....	.....	.....	
		L.....	3 30 ..	23	.....	.....	.....	
		L.....	3 45 ..	13	.....	.....	.....	
		F.....	4 50 ..	.....	.....	.....	.....	
2	.....	e.....	16 59 *to*	14	.....	.....	.....	
		F.....	17 10 ..	.....	.....	.....	.....	
3	.....	e.....	18 02 35	.....	.....	.....	.....	May not be seismic; on Milne-Shaw only.
			to 11 15	.....	.....	.....	.....	
4	.....	e?.....	5 42 30	.....	.....	.....	.....	Irregular faint trace.
		e.....	5 44 30	.....	.....	.....	.....	
		F.....	6 13 ..	.....	.....	.....	.....	
4	.....	0.....	(8 12 36)	.....	.....	.....	(6,180)	
		eP?...	(8 22 17)	.....	.....	.....	.....	
		iS?....	8 30 03	.....	.....	.....	.....	
		eL....	8 39 30	.....	.....	.....	.....	
		L.....	8 45 ..	15	.....	.....	.....	
		L.....	9 20 ..	10	.....	.....	.....	
		F.....	9 55 ..	.....	.....	.....	.....	
4	.....	eL....	23 55 *to*	.....	.....	.....	.....	Sinusoidal L waves; small amplitude.
5	.....	L.....	0 05 ..	18	.....	.....	.....	
5	.....	e.....	16 13 ..	.....	.....	.....	.....	Faint traces on Milne-Shaw only; irregular.
		L.....	16 38 ..	.....	.....	.....	.....	
6	.....	e.....	6 06 ..	.....	.....	.....	.....	Sinusoidal L waves; very small; M-S only.
		L.....	6 15 ..	17	.....	.....	.....	
7	.....	e.....	6 24 45	.....	.....	.....	.....	
		e.....	6 29 40	.....	.....	.....	.....	
		L17...	6 40 *to*	14	.....	.....	.....	
			6 45 ..	.....	.....	.....	.....	
		F.....	7 05 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, July 1923*—Continued.

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.								
July 7		eL	13 40 *to*					Sinusoidal L waves; small amplitude; beginning lost changing sheets.
		L	13 46 ..	20				
		L	13 53 *to*					
			14 00 ..	14				
		F	14 15 ..					
10		e?	0 41 ..					
		iS?	0 50 32					
		eL?	1 00 30					
		L	1 25 ..	13				
		L	1 45 ..	12				
		L	2 08 ..	12				
		L	2 31 ..	12				
		L	3 06 ..	12				
		F	3 30 ..					
10		e?17	5 48 ..					Very small amplitudes; on M–S No. 17 only.
		eL17	6 00 to					
		L17	6 10 ..	15				
		F	6 25 ..					
12		*O*	(3 19 40)				(10340)	eP doubtful; agreement of other phases extraordinarily good.
		ePll	(3 32 58)					
		i17	3 34 44					
		iS17	3 44 17					
		SR1	3 50 37					
		eL17	4 06 30					
		L	4 10 *to*					
		L	4 15 ..	23				
		L	4 20 *to*					
		L	4 35 ..	17				
		L	4 50 *to*					
		L	5 10 ..	15				
		L	5 15 ..	15				
		LR1	5 27 ..	21				
		L	5 33 *to*					
		L	5 42 ..	16				
		F	6 10 *ca.*					
12		el7	9 42 07					
		eS?17	9 43 40					
		eL17	10 06 ..	32				
		L	10 13 ..	21				
		L17	10 17 ..	16				
		L17	10 29 ..	14				
		L17	10 40 ..	14				
		F	11 05 ..					
13		*O*	11 14 45				9,520	M about same time period, and amplitude on three types of seismograph; agreement good as to distance.
		P	11 27 24					
		PR1	11 31 25					
		S	11 38 00					
		eL	11 58 00					
		L	12 06 ..	29				
		M	12 16 ..	17	60			
		L	12 30 ..	17				
		L	13 00 ..	15				
		F						Lost changing sheets about 13:30.
13		el7	16 47 40					
		eL17	16 57 *to*					
		L17	17 09 ..	16				
		F	17 12 ..					
14		e	0 20 40					
		e	0 30 40					
		eL	0 42 ..	32				
		L	0 51 ..	25				
		L	0 59 ..	18				
		L	1 13 ..	16				
		L	1 26 ..	16				
		L	1 42 ..	12				
		F	2 00 *ca.*					
16		el7	13 58 36					L waves sinusoidal; small amplitude; P on Milne-Shaw only.
		i17	14 04 15					
		i17	14 05 36					
		i17	14 08 29					
		i17	14 10 20					
		eS?	14 14 58					
		eL?17	14 36 ..					
		L	14 38 *to*	23				
		L	15 00 ..	15				
		L	15 10 ..	15				
		L	15 56 ..	17				
		F	16 30 ..					
17		e?	1 10 15					Irregular L, small amplitude.
		e	1 16 43					
		e	1 20 00					
		eL?	1 23 36					
		L	1 33 ..					
		F	1 38 ..					
18		*O*	1 05 55				3,600	Small record; very good agreement.
		P	1 12 43					
		S	1 18 07					
		eL	1 22 *to*	29				
		L	1 27 ..	15				
		F	2 *ca.*					

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.								
July 18		*O*	6 02 13				3,580	Undoubtedly same epicentre as preceding.
		P	6 09 00					
		S	6 14 22					
		eL	6 18 30	29				
		L	6 28 ..	15				
		F	7 00 ..					
20		i	5 06 00					Very small traces of L on Milne-Shaw only.
		eL	5 20 ..					
		F	5 45 ..					
20		e	15 14 00					Milne-Shaw only. Strasbourg gives P 15:12:00, distance, 6000. No. 23 not in operation after July 20.
		i	15 23 45					
		eL	15 31 ..					
		L	15 36 ..	28				
		L	15 47 ..	16				
		L	16 05 ..	14				
		F	16 52 *ca.*					
21		eL	14 13 30					
		L	14 21 *to*					
		L	14 30 ..	13				
		L	14 40 ..					
		F	14 45 ..					
22		*O*	14 18 07				7,320	Continued L waves, sinusoidal, small amplitudes.
		P	14 28 52					
		S	14 37 40					
		SR1	14 45 30					
		eL	14 51 ..					
		L	15 06 ..	13				
		L	15 35 ..	12				
		F	17 00 *ca.*					
23		e?	7 38 10					Irregular L waves; small amplitude; short period.
		e	7 48 00					
			to 55 ..					
		F	8 10 ..					
26		eL	(8 10) ..	23				Sinusoidal L waves only; time uncertain.
		L	(8 40) ..	15				
		F	(9 00) ..					
26		eL	(10 50) ..	30				Do.
		L	(11 15) ..	15				
		F	(11 50) ..					
30		eL	23 53 ..	20				Milne-Shaw only.
31		L	0 05 ..	10				
		F	0 10 ..					
31		i	5 53 59					
		i	5 54 48					
		e	5 59 ..					
		L	6 01 ..	9				
		F	6 20 ..					
31		e	15 23 00					
		e	15 27 30					
		e	15 39 50					
		e	15 41 10					
		eL	15 42 ..	17				
		L	16 18 ..	10				
		F	17 15 ..					

Reports for July, 1923, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

ALASKA. *U. S. C. & G. S. Magnetic Observatory*, Sitka.

ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.

MASSACHUSETTS. *Harvard University*, Cambridge.

MISSOURI. *St. Louis University*, St. Louis.

NEW YORK. *Cornell University*, Ithaca; *Fordham University*, New York.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

CANADA. *Meteorological Service of Canada*, Toronto *and* Victoria.

TABLE 3.—*Late reports (instrumental).*

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1923.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
May 1	.....	e.....	10 54 ..	.....	.....	.....	.....	Heavy micros.
		eS?....	11 00 49	.....	.....	.....	.....	
		F.....	11 30 *ca.*	.....	.....	.....	.....	
2	.....	e.....	16 41 ..	.....	.....	.....	.....	Heavy micros.
		eL_E?..	16 43 ..	.....	.....	.....	.....	
		L_E....	16 45 ..	.....	.....	.....	.....	
		L_N....	16 46 44	11	.....	.....	.....	
		F.....	17 20 ..	.....	.....	.....	.....	
4	.....	eP_E...	16 36 02	.....	.....	.....	.....	Micros.
		eP_N...	16 36 03	.....	.....	.....	.....	
		S.....	16 43 34	.....	.....	.....	.....	
		eL.....	16 51 24	7	.....	.....	.....	
		M_E....	16 57 04	.....	*5800	.....	.....	
		M_N....	16 57 29	.....	.....	*3700	.....	
		F.....	19 *ca.*	.....	.....	.....	.....	
4	.....	e.....	22 37 26	.....	.....	.....	.....	
		S.....	22 47 11	.....	.....	.....	.....	
5	.....	F.....	0 20 *ca.*	.....	.....	.....	.....	
5	.....	e_N.....	9 58 ..	.....	.....	.....	.....	
		F.....	10 10 ..	.....	.....	.....	.....	
5	.....	e_N.....	15 18 ..	.....	.....	.....	.....	Very heavy micros; E W. obscure.
		eL_N...	15 24 24	.....	.....	.....	.....	
		F_N....	16 *ca.*	.....	.....	.....	.....	

DISTRICT OF COLUMBIA. *Georgetown University, Washington*—Con.

1923.								
July 12	.....	eP_E...	1 39 44	.....	.....	.....	.....	Very heavy micros.
		iP_N...	1 39 44	.....	.....	.....	.....	
		S?.....	1 49 54	.....	.....	.....	.....	
		F.....	3 *ca.*	.....	.....	.....	.....	
23	.....	eP_N...	22 48 47	.....	.....	.....	.....	Heavy micros; P_E does not show; no distinct M.
		S?.....	22 57 04	.....	.....	.....	.....	
		eL_E...	23 07 30	.....	.....	.....	.....	
		L_E....	23 14 19	27	.....	.....	.....	
		L_N....	23 14 30	22	.....	.....	.....	
24	.....	F.....	0 54 ..	.....	.....	.....	.....	
28	.....	e_E.....	1 48 53	.....	.....	.....	.....	Heavy micros.
		e_N.....	1 48 30	.....	.....	.....	.....	
30	.....	e_E.....	16 07 24	.....	.....	.....	.....	Heavy micros.
		e_N.....	16 07 20	.....	.....	.....	.....	
		eL_E?..	16 27 18	19	.....	.....	.....	
		L_E....	16 33 24	19	.....	.....	.....	
		L_N....	16 34 ..	.....	.....	.....	.....	
		F.....	16 55 ..	.....	.....	.....	.....	
31	.....	e?.....	22 11 38	.....	.....	.....	.....	Very heavy micros.
		eL_E...	22 21 36	21	.....	.....	.....	Difficult.
		F.....	22 35 ..	.....	.....	.....	.....	

* Trace amplitude.

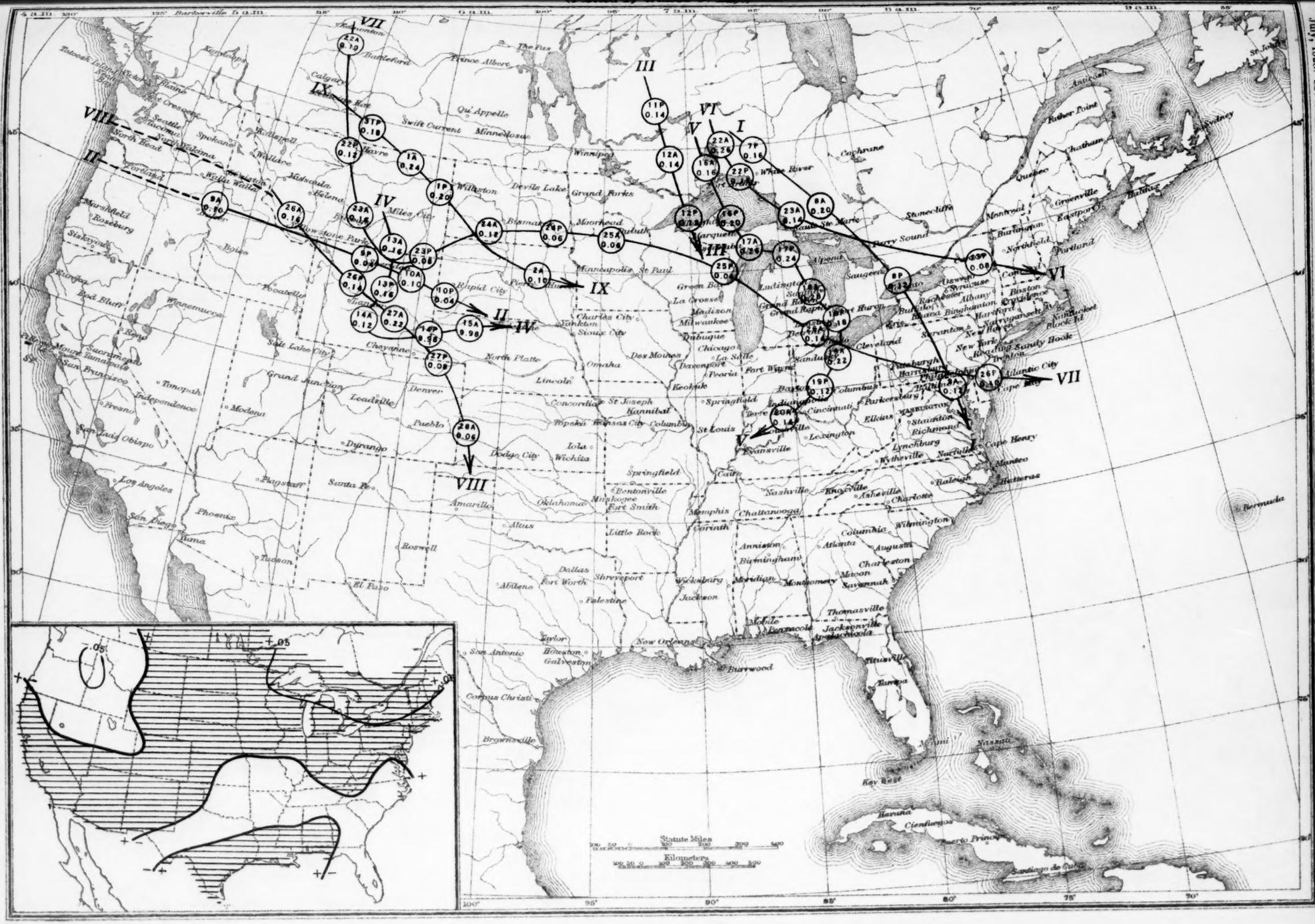

VII
IX
VIII
II
IV
III
VI
V
I
Statute Miles
Kilometers

Chart II. Tracks of Centers of Cyclones, July, 1923. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

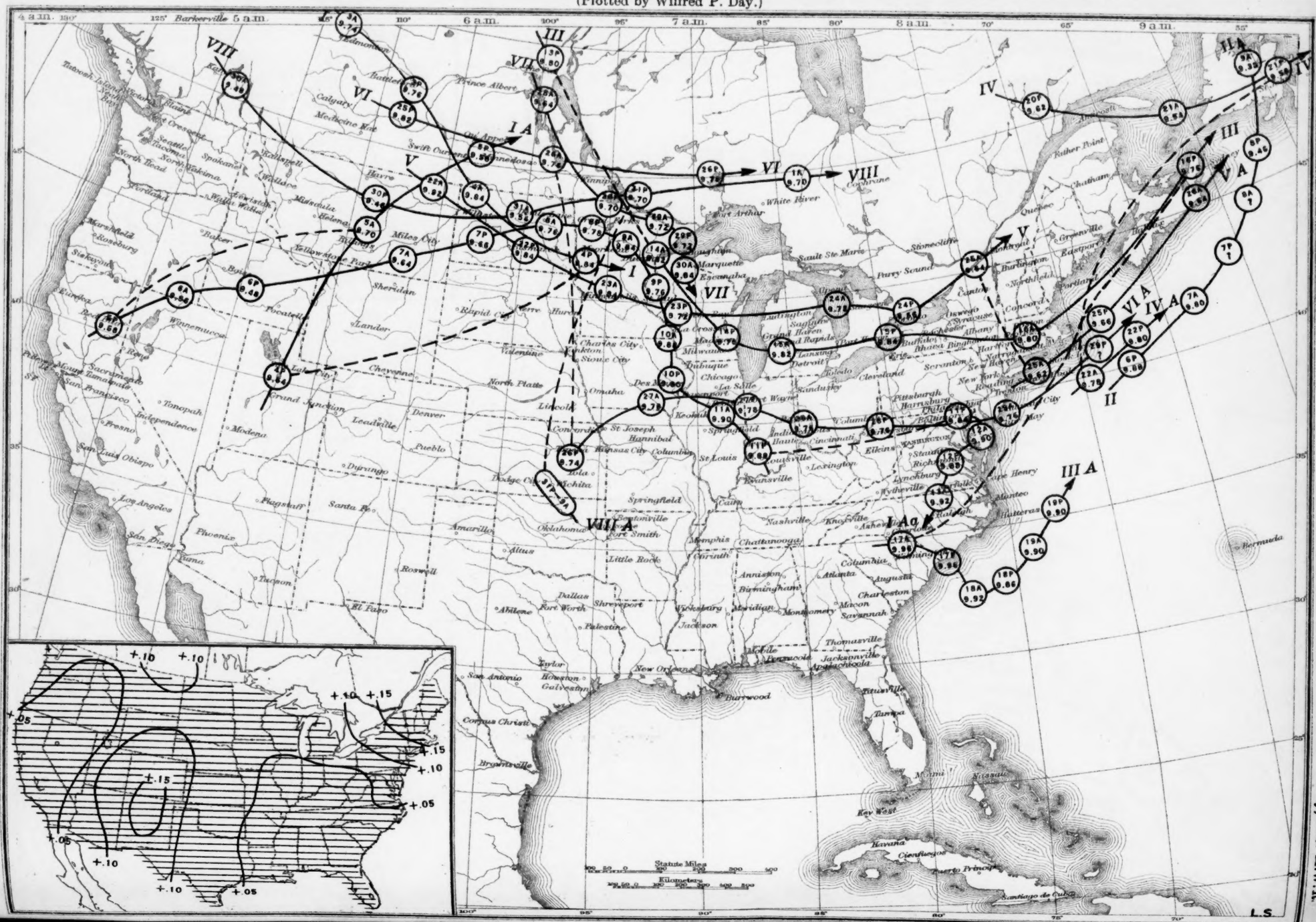


Chart III. Departure (°F.) of the Mean Temperature from the Normal, July, 1923.

Chart III. Departure (°F.) of the Mean Temperature from the Normal, July, 1923.

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart IV. Total Precipitation, Inches, July, 1923. (Inset) Departure of Precipitation from Normal.

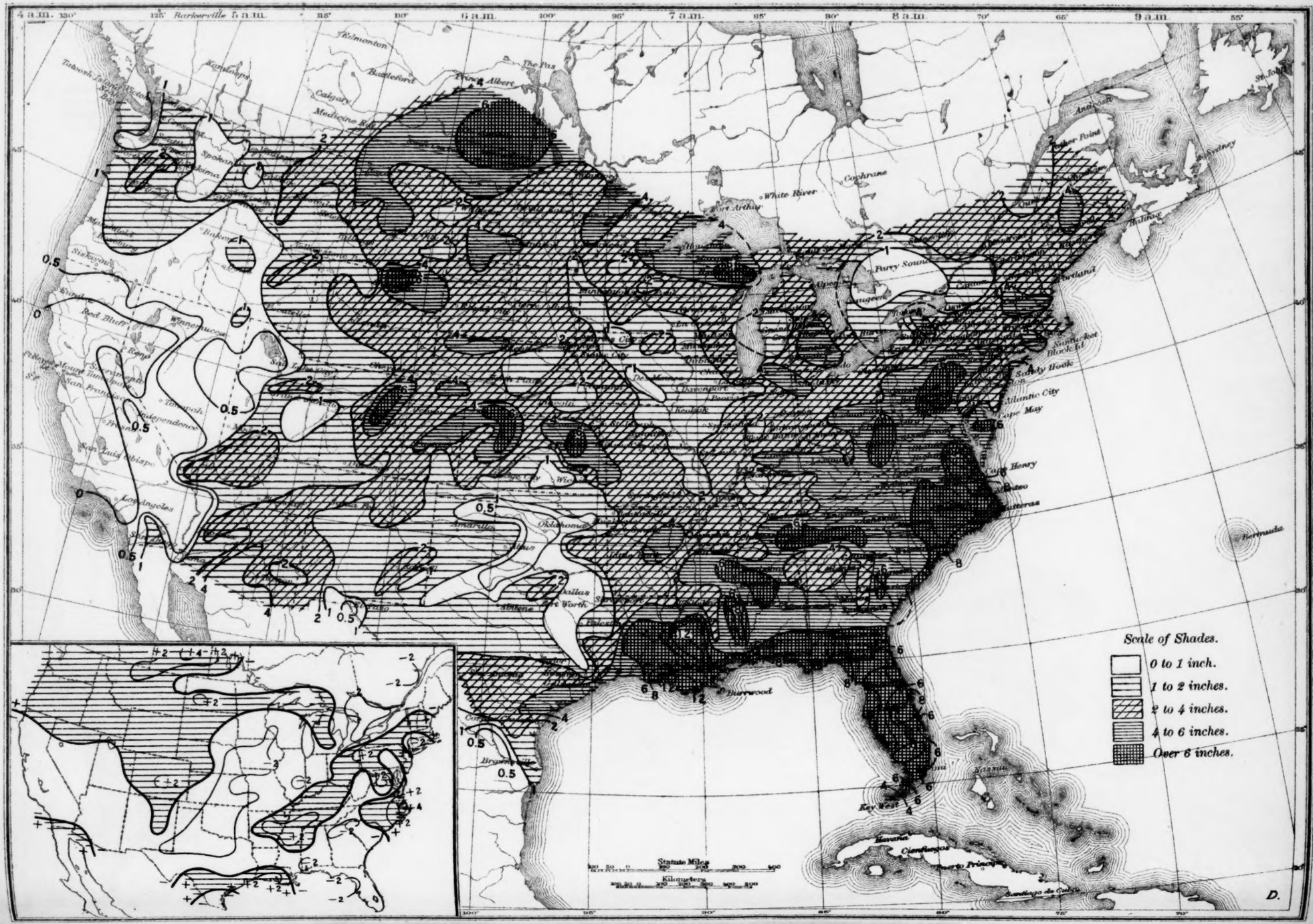


Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1923.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1923.

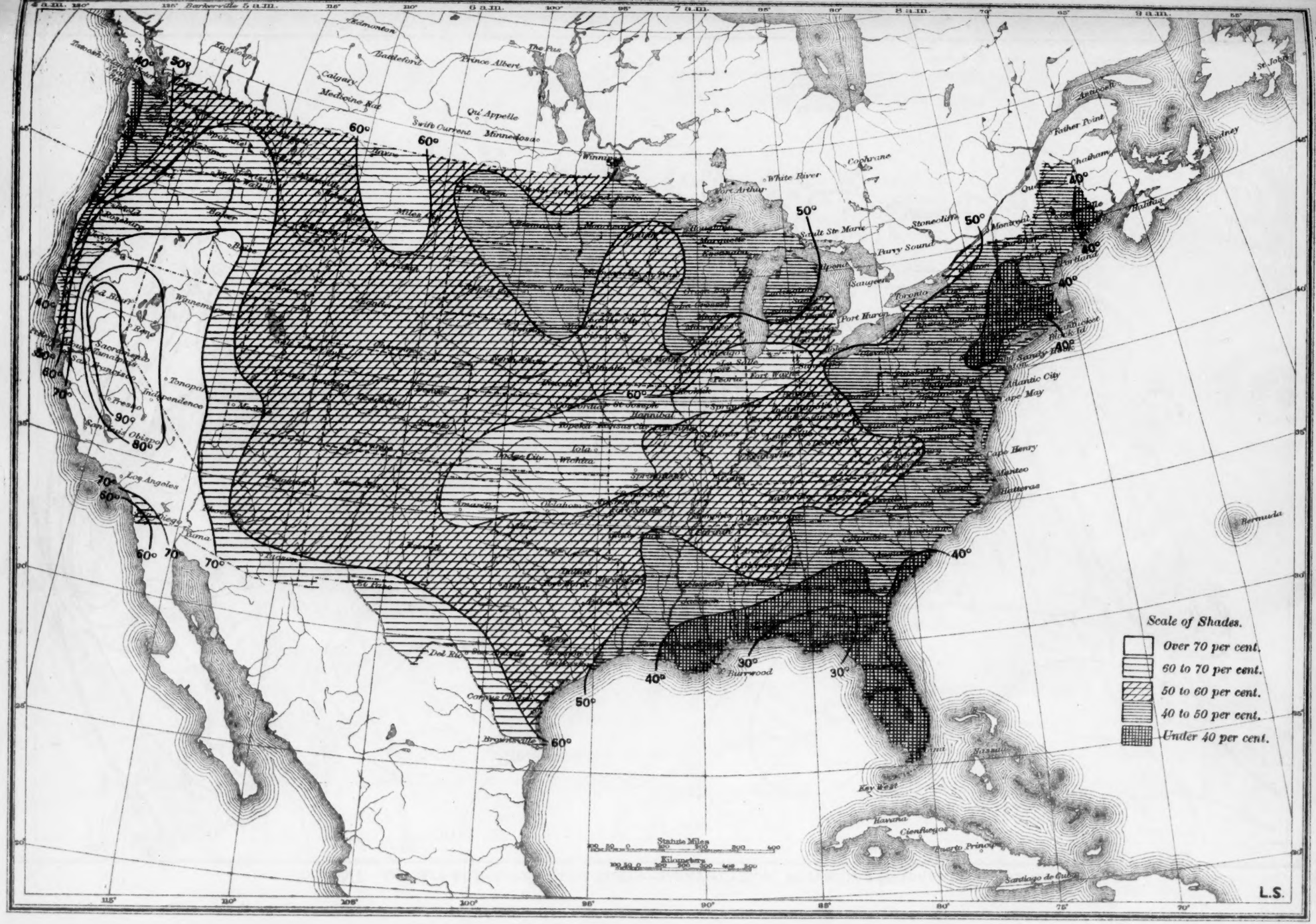
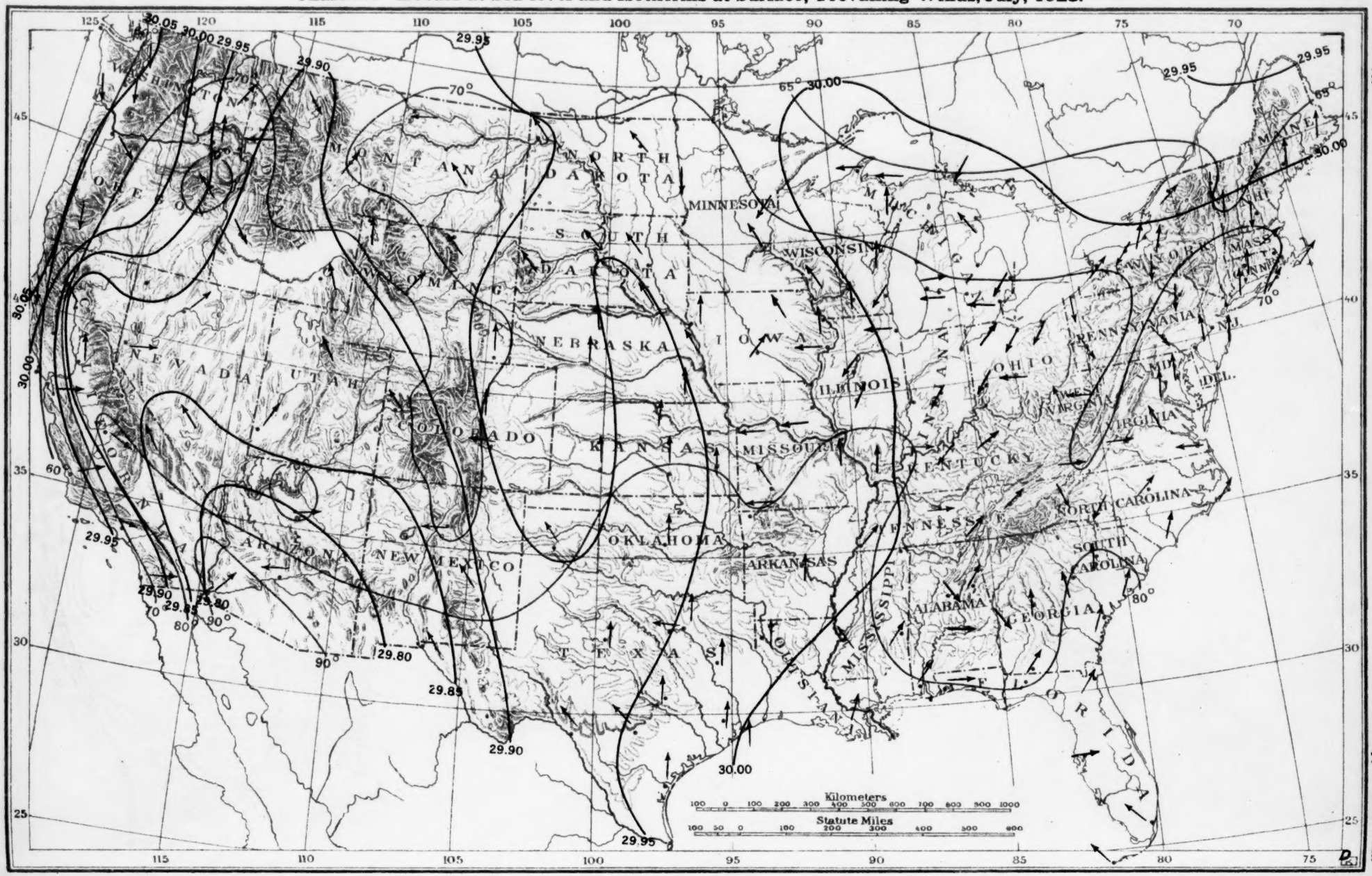


Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, July, 1923.



(Plotted by F. A. Young.)

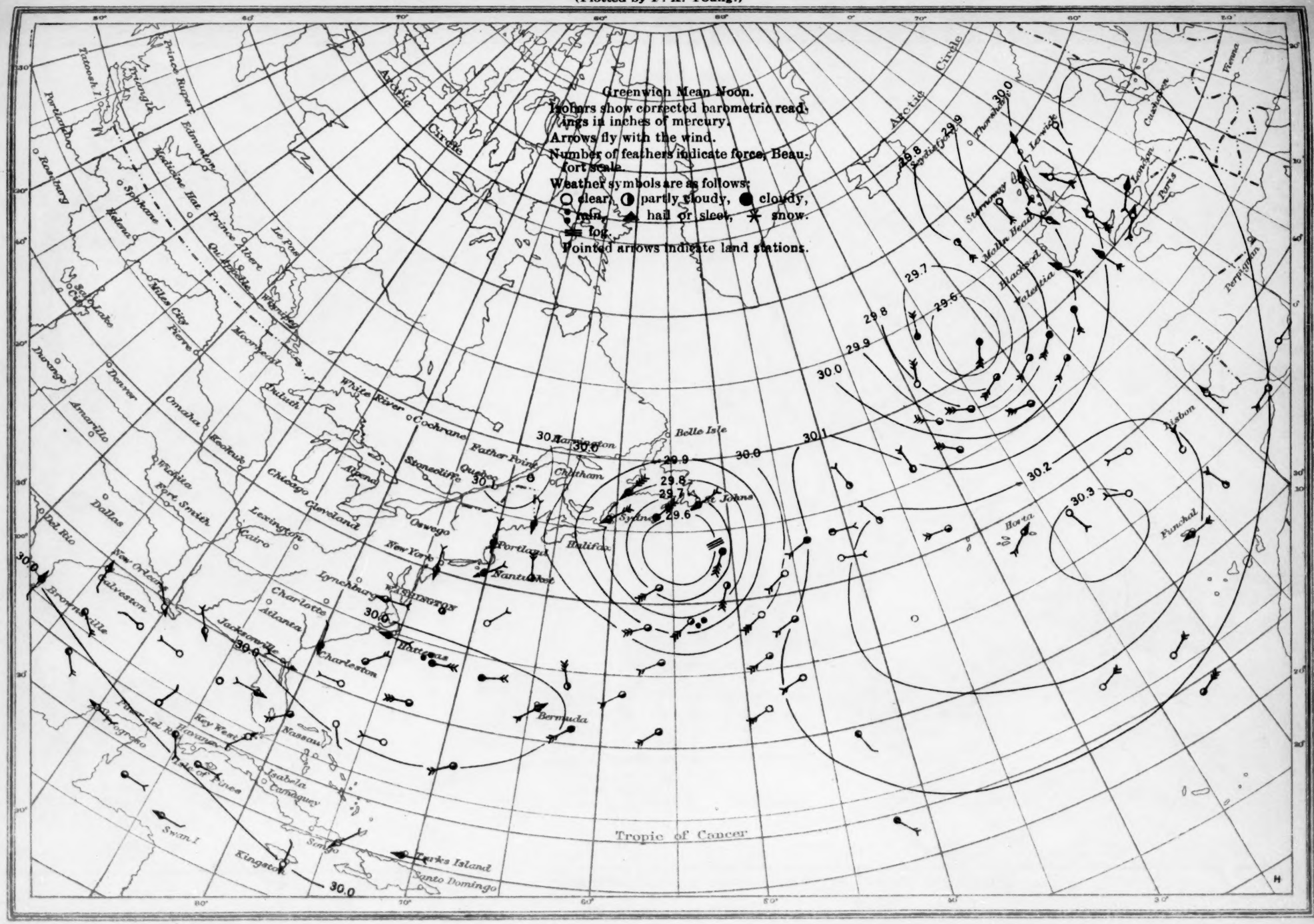
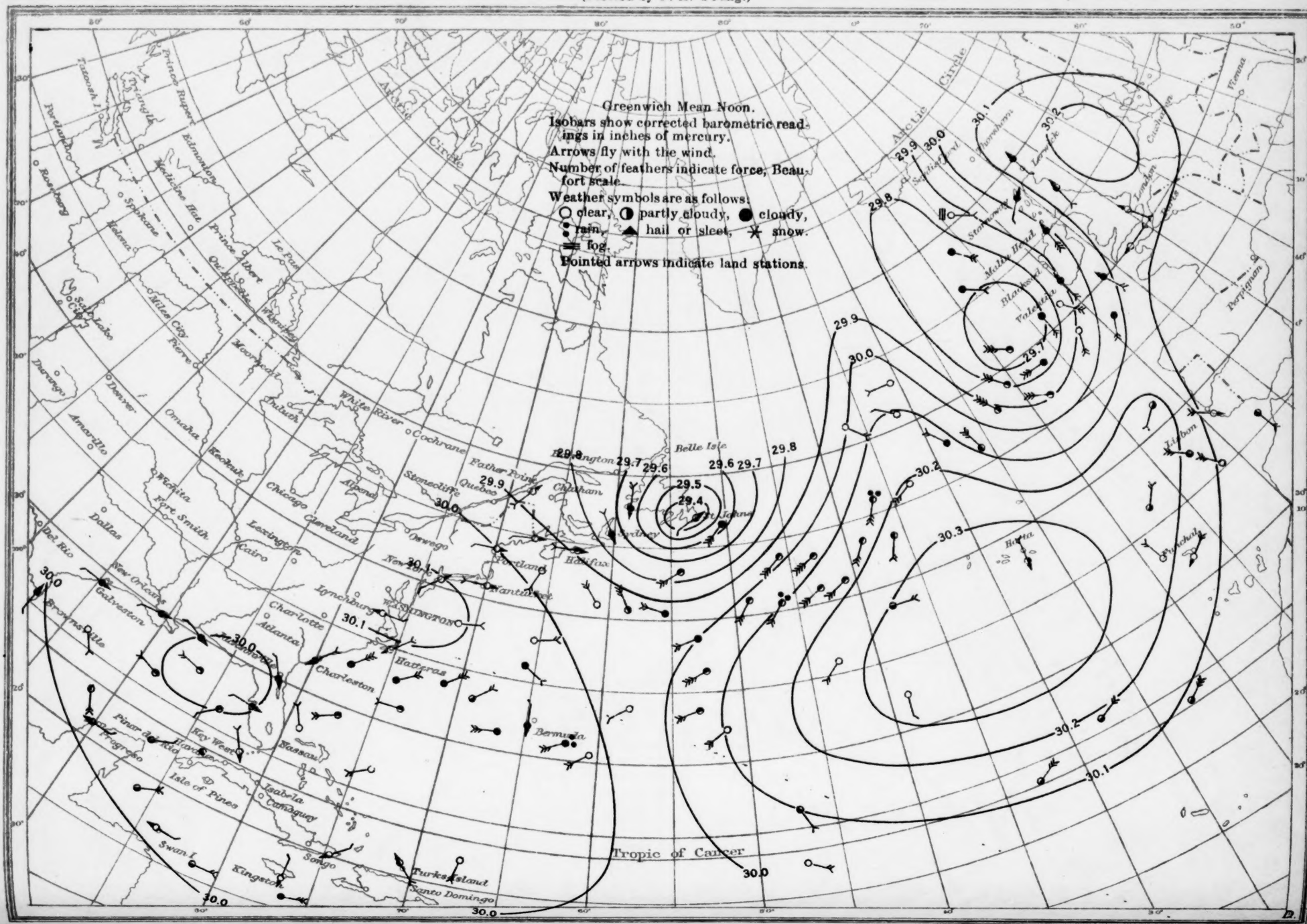


Chart IX. Weather Map of North Atlantic Ocean, July 9, 1923.

(Plotted by F. A. Young.)